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TAKEOFF AND LANDING ANALYSIS COMPUTER PROGRAM (TOLA). PART III. USER'S MANUAL

Urban H. D. Lynch, et al

Air Force Flight Dynamics Laboratory
Wright-Patterson Air Force Base, Ohio

April 1974

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(Form 1473 Continued)

The TOLA program is ideal for dynamic tradeoff studies in aircraft design, landing gear design, and landing techniques. The formulation is programmed for the CDC 6000 and Cyber 70 Computer Systems. The program is programmed in Fortran Extended using the Scope 3.4 operating system.

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13. ABSTRACT

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The basic program provides six rigid-body degrees of freedom of aerospace vehicle motion over a flat planet and determines the response of the aircraft to control inputs. The dynamics of up to five independent oleo-type struts are included for simulation of symmetrical and nonsymmetrical landings as well as drop tests.

A maneuver logic is programmed to provide vehicle guidance in the various phases of the problem; it determines the desired trim and position in the glide slope and provides synthesis and attempted completion of necessary flare dynamics for prescribed touchdown velocity vector. The landing roll includes wheel spinup and braking, thrust reversing, spoiler deployment, and system failure options. The takeoff roll consists of acceleration to takeoff speed, followed by rotation to takeoff angle of attack.

The autopilots attempt to obtain smooth response with no overshoot and provide values for pitch, yaw, and roll control surface deflections, throttle settings for one, two, three, or four engines, and controlled (or failed, locked or constant) braking. The control response logic simulates linear control system rates and their corresponding lags to desired values.

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Computer Program						
Glide Slope						
Flare						
Landing Roll						
Takeoff Roll						
Landing Gear Loads and Dynamics						
Vehicle Control						

AFFDL-TR-71-155
Part III

TAKEOFF AND LANDING ANALYSIS COMPUTER PROGRAM (TOLA)

Part III. User's Manual

Urban H. D. Lynch, Major, USAF
John J. Dueweke

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FOREWORD

Work described in this report was accomplished by the Flight Mechanics Division of the Air Force Flight Dynamics Laboratory and the Digital Computation Division of the Aeronautical Systems Division under Project 1431, "Flight Path Analysis," Task 143109, "Trajectory and Motion Analysis of Flight Vehicles." The formulation and interim documentation were completed by Major Urban H. D. Lynch. Programming was accomplished by Mr. Fay O. Young of the Digital Computation Division (ASVCP), Computer Science Center, Aeronautical Systems Division.

This report was prepared by Major Lynch and Mr. John J. Dueweke of the High Speed Aero Performance Branch (FXG), and combines the applicable portions of FDL-TDR-64-1, Part I, Volume I, with the interim documentation. The overall report is divided into four parts:

Part I.	Capabilities of the Takeoff and Landing Analysis Computer Program
Part II.	Problem Formulation
Part III.	User's Manual
Part IV.	Programmer's Manual

This report was submitted by the authors in June 1972.

This technical report has been reviewed and is approved.

PHILIP P. ANTONATOS
Chief, Flight Mechanics Division
Air Force Flight Dynamics Laboratory

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TOLA is an acronym for TakeOff and Landing Analysis digital computer program. This part describes the use of the program.

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The TOLA program is ideal for dynamic tradeoff studies in aircraft design, landing gear design, and landing techniques. The formulation is programmed for the CDC 6000 and Cyber 70 Computer Systems. The program is programmed in Fortran Extended using the Scope 3.4 operating system.

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SECTION I

INTRODUCTION

The purpose of this report is to summarize and complete the documentation of Project 143109-002 "Take Off and Landing Analysis", (TOLA). TOLA is a FORTRAN modification to Option 2 (SDF-2) of FDL-TDR-64-1, "Six-Degree-of-Freedom Flight Path Study Generalized Computer Program", and allows comprehensive, quantitative calculation of aircraft takeoff and landing performance. Specifically, this report shows how to use the TOLA computer program.

The reader should at least familiarize himself with the formulation documentation before attempting to use the TOLA simulation. This documentation is contained in Volume I of this report, and in AFFDL-TR-68-111, which formulates the equations of motion for a series of nonrigid bodies.

The performance analyst will need to obtain data on the various components of a given vehicle. The types of data required are summarized under TOLA Inputs. Data Format details how the data is used.

SECTION II

TOLA INPUTS (Specify Units)

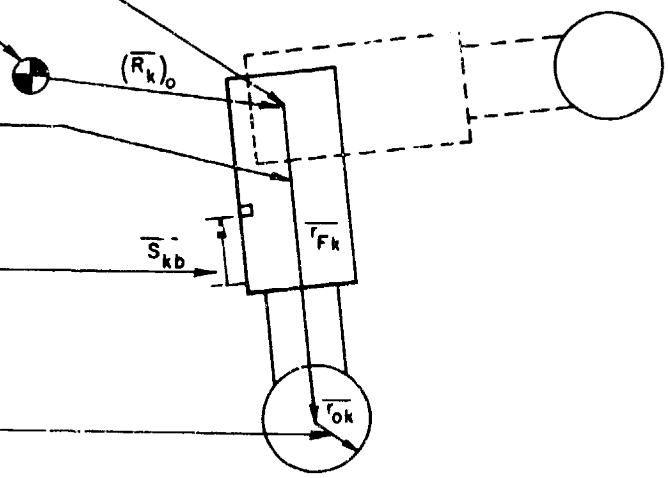
1. VEHICLE DATA

   Either TOGW or landing weight

   Ixx, Iyy, Izz, Ixz cg location (W.L., body station)

2. LANDING GEAR DATA

   For Each Gear:



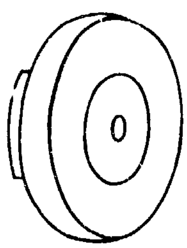
Gear pin locations relative to cg, (RX, RY, RZ)

Fully extended displacement of axle from gear pin, RF

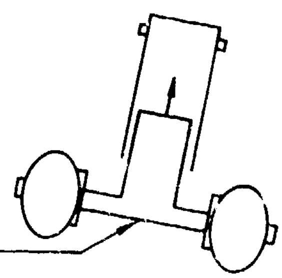
Maximum strut stroke to compression stop, SB

Tire radius, RZERO

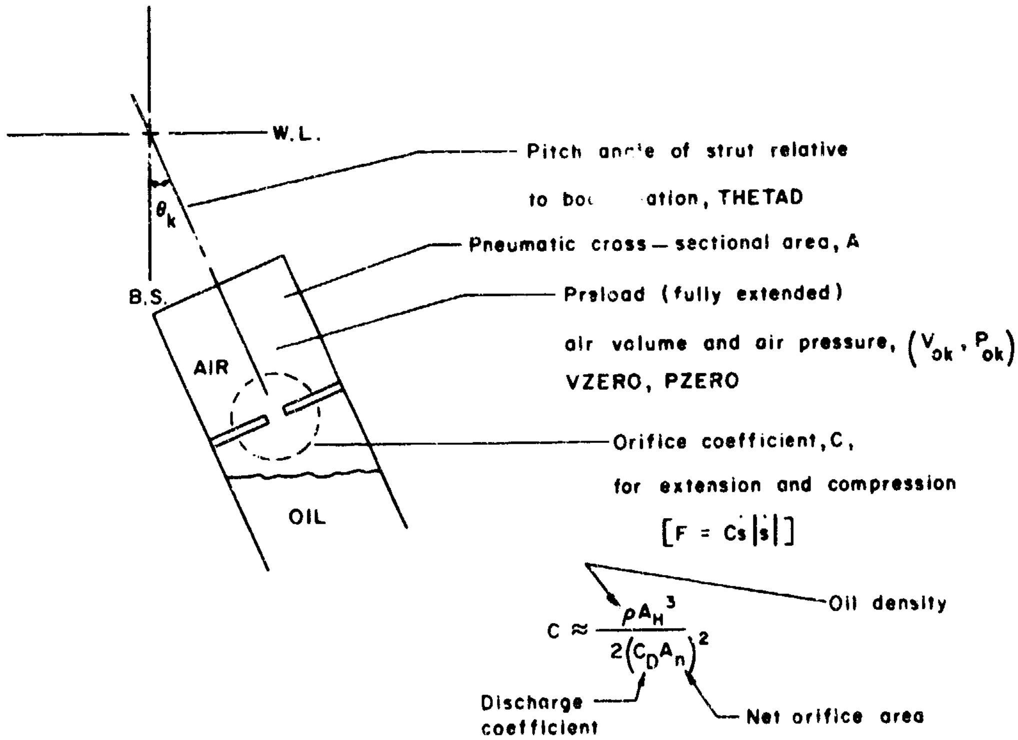
Number of tires on each gear, (n_k) NTIRES



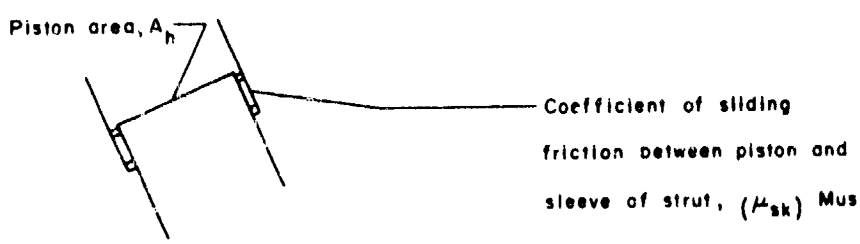
Moment of inertia of a tire, wheel, and anything else constrained to rotate with the tire about the axle, (I_k) MOMENT

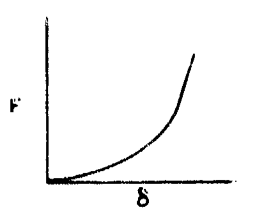


Mass of all portions of strut which move relative to outer sleeve of strut, (m_k) MASS



If there is a metering pin, $A_n = A_n(s)$ implying $C = C(s)$.





Tire Force – Deflection Curve (s)

OR

$$F = a_i \, \delta^{b_i}$$

[from
$\log F = \log a_i + b_i \log \delta$]

3. AERODYNAMIC DATA

Aerodynamic Reference Area AREFF

Longitudinal Reference Length (usually M.A.C.) DIRFF

Lateral Reference Length (usually span) D2RFF

"Wind" Axes (with and without spoilers)

C_D vs. α for various elevator deflections

C_L vs. α for various elevator deflections

"Body" axes

C_m vs. α for various elevator deflections

(Origin of moment axis system [W.L., B.S.])

C_ℓ vs. β "aileron" deflection

C_n vs. β for various rudder deflections

C_y vs. β

C_{ℓ_p}, C_{mq}, C_{n_r}

Of the above listed coefficients, the first 3 are mandatory. The next 3 are required if crosswinds or engine failures are to be studied. The rate coefficients may be input, also, if available.

Provision is made for coefficients with no ground effect and including full ground effect.

ΔC_D due to gear.

4. PROPULSION DATA

"Installed" thrust as a function of Mach No. and "throttle setting." Thrust vector(s) assumed parallel to body x-axis; thus, the body y- and z-axis displacements of the thrust vector( ), YN, ZN, are required. Mass is assumed constant (therefore, No fuel is required).

5. RUNWAY DATA

Length (R_L) - RLT

Altitude above sea level - RWHGR

Elevation angle relative to horizontal (E_R) - ERDEG

6. OPTIONAL DATA

Reverse thrust

Drag chute; requires chute C_D, S_{REF}, and location of chute attachment point relative to c.g.

Wheel braking, including "controlled" braking based on a commanded "skid"

Engine failure(s)

Control variable rate lags

Effects of rotating machiner, including:

Rotation rate of machinery about its own shaft (ω_r) - ØMGRT

Pitch angle of shaft relative to body x-axis in plane parallel to body x-z plane (θ_r) - THTRD

Moment of inertial of rotating machinery about its own shaft (I_{xr}) AIXR7S

7. OTHER REQUIRED DATA

The lower and/or upper limits on the following variables are required.

Type Data	Computer Symbol
Tire deflection (for blowout)	DELTAM
Braking moments	MBL, MBU
"% skid" for controlled braking	PD
Control angular acceleration of wheel to the angular speed required to maintain a given "%" skid"	OMECD1
Angle of attack	ALPHDS, ALPHDL
Angle of attack rate	ALPDL

Type Data	Computer Symbol
Elevator deflection	DELQL, DELQU
Aileron deflection	DELPL, DELPU
Rudder deflection	DELRL, DELRU
Elevator deflection for takeoff, landing roll	DELQTO
Elevator deflection rate for landing roll	DELFD1
Thrust: Throttle setting above which reverse throttle should not be engaged	NB
Time to activate spoilers (t_{sp})	TSP
Time to reverse engines (t_{rv})	TRV
Time to release drag chute (t_{ch})	TCH
Time to initiate wheel braking (t_{bk})	TBK
Linear rates for simulating control response lags:	
Elevator rate	DELHS
Aileron rate	DELA
Rudder rate	DELRRD
Throttle rate	NED1

SECTION III

DATA FORMAT

1. CARD FORMAT

The program input routine (READ) expects the following format.

Card Columns	1 - 6	7	8 - 10	11	12 - 66	67 - 72	73 - 80
Field	I	II	III	IV	V	VI	VIII

Card Field I - Contains the symbolic name of the variable which data contained in Field V begins loading. Example: Card Column

1	12
GAM7D	-1.23
SIG7D	90.

Card Field II Not used

Card Field III - Contains the words DEC, ØCT, BCD, TRA, INT, or is blank, depending on the type of data to be loaded. The word ØCT indicates that the data is to be interpreted as octal numbers. The word BCD specifies that N binary coded decimal words (N punched in column 12) beginning in column 13 are to be loaded. The word TRA denotes to the input routine that all data has been input and to return control to the calling program. The word DEC and blank are equivalent and specifies that data loaded is decimal data.

ØCT Example			
Card Column	1	8	12
	NSMAIN	OCT	17
BCD Example			
Card Column	1	8	12
	REM	BCD	3SDF2-GEAR-MOD

The 3 in Column 12 specifies 3 words where each word is considered to be 6 characters including blanks. The largest number of 6 character words that can be loaded from one card is 9. Analysts should be very careful to see that the BCD information does not get punched into Field VI. This will cause an input error.

DEC Example

Card Column	1	8	
	VTAB01	DEC	2,0.,1.67,20000.,1.67

Note that the first character in Column 12 is an integer and the input routine will load only one integer per DEC card and that has to be the first number punched in Field V.

VTAB01	DEC	2.,0.,1.67,20000.,1.67

If the above card is punched, the two will now be loaded into the machine as a binary floating point number. Likewise, the other numbers will be loaded the same with the decimal point assumed right justified.

If anything other than OCT, BCD, INT, TRA or blank appears in Field II then the word DEC is assumed.

INT Example

Card Column	1	8	12
	IP	INT	1
	IP		1
	IP	INT	1,1,1,1

When the word INT is used, it is assumed that all numbers on the card will be loaded as integers. If only one integer is punched per card the INT may be punched or omitted.

Card Field IV - Not Used

Card Field V

The actual input data to the program is punched in the Field V. DEC, INT and ØCT numbers must always be left adjusted; that is, data must always start in column 12 on the input card. All numbers are separated by a "comma" and the field terminates with the first blank. BCD information begins in Column 13 and the maximum number of 6-character words per card is nine. Note that since Field V ends with the first blank, the user may punch any comments in the remainder of the field.

Card Field VI

This field specifies the initial subscript of the data in Field V. If this field is blank an initial subscript of 1 is implied. The subscript may appear anywhere within the field.

Example			
Card Column	1	12	67
	PZERØ	30470.4,41538.24,41538.24	1 or blank)
	PZERØ	42538.24,42538.24	4

In the example above, the number 30470.4 is loaded into the first cell of the array PZERØ. On the second card 42538.24 is loaded into the fourth cell of the array. The one and four punched in Field VI indicate the subscript for the array PZERØ.

Card Field VII

Not used as far as the input routine is concerned. This may be used as a sequence number for the card.

2. TABLE FORMAT

The various types of tables used by the program may be classed as follows:

One-Dimensional Tables

Example 1:	NTIRES	$n_i = f(i)$, $i = 1,2,\ldots,$NSTRUT
Card Column	1	12
	NSTRUT	5
	NTIRES	4.,6.,6.,6.,6.

NSTRUT = Fixed point number which is the number of struts on the aircraft. For example, the number of tires on strut #2 is 6. i.e., $n_2 = f(2) = 6.$

i = Independent variable values

n_i = Corresponding dependent variable values

Example 2: Aerodynamic Data

Card Column	1	12
	INDA01	1
	ATAB01	.0065,.00748

INDA01 $\neq$ 1 designates that there are data in ATAB01. The first data point is for full ground effect; the second data point is for no ground effect in all aerodynamic tables.

Two-Dimensional Table

Example:	VTAB01	$X_{CG} = f(M)$
Card Column	1	12
	VTAB01	$N, M_1, X_{CG_1}, M_2, X_{CG_2}, \ldots, M_N, X_{CG_N}$

N = Fixed point number equal to 2 times the number of independent variables. For a 20 point table, N would equal 20. The total number of machine cells required for this table is 41.

M_i = Independent variable values

X_{CG_i} = Corresponding dependent variable values

N - Dimensional Table

Example:	$T = F(N, M_N)$		
Card Column	1	12	67
	IT10W	NN	
	IT10X	NMN	
	TTAB10	$N_1, N_2, N_3, \ldots, N_{NN}$	1
	TTAB10	$M_{N_1}, M_{N_2}, M_{N_3}, \ldots, M_{NNMN}$	*
	TTAB10	$T_{N_1}, M_{N_1}, T_{N_2}, M_{N_1}, \ldots, T_{N_{NN}}, M_{N_1}$	*
	TTAB10	$T_{N_2}, M_{N_2}, T_{N_2}, M_{N_2}, \ldots, T_{N_{NN}}, M_{N_2}$	*
	TTAB10	$T_{N_1}, M_{NNMN}, T_{N_2}, M_{NNMN}, \ldots, T_{N_{NN}}, M_{NNMN}$	*

NN and NMN are fixed point numbers of independent variables. $T_{N_1}, M_{N_1}, \ldots, T_{N_{NN}}, M_{NNMN}$ are values of independent variables. The table subscripts

*Displacement numbers required when any table exceeds (1) card. See example, page 9.

would apply to the N-dimensional table as well as the two dimensional. The total number of machine cells required for an N-dimensional table equals NN * NMN + NN + NMN. (Asterisk here indicates multiplication.)

Examples:

C = F(X, Y)	NX = 2 = points for X NY = 2 = points for Y
Machine cells required	2 x 2 + 2 + 2 = 8 cells
C = F(X, Y,Z)	NX = 20 = points for X NY = 10 = points for Y NZ = 15 = points for Z
Machine cells required	20 X 10 X 15 + 20 + 10 + 15 = 3045 cells

SECTION IV

DATA PREPARATION

1. DATA PREPARATION - GENERAL

Before preparing data which may actually affect the trajectory, a certain amount of data must first be considered, including:

a. Table size data

b. Identification data

c. Required data input for each case

d. Integration data

These are pointed out in the sections to follow.

a. Table Size Data

Table sizes are read into the program by data cards that follow an STCASE TAB card. All tables are assumed dimensional (1) unless otherwise specified by data input.

Example: Define tables TTAB10 (30), ATAB01 (2), and VTAB01 (5).

Column	1	8	12	
	STCASE	TAB		(define tables and Base case)
	TTAB01		30	
	ATAB01		2	
	VTAB01		5	
		TRA		(END table definition) Stage 1 data follows this TRA card.

Tables can only be defined in a Base Case. The sum of all table sizes may not exceed 600 without a program modification to COMMON block COMMON/TABDIR/ in routines AUXR2, TLU, HIHO, TFFS, and AERO.

The table size definition in the Base Case must be sufficient for any table in a succeeding Merge Case with a larger table size than that found in the Base Case.

b. identification data

a. Remarks. For identification purposes, three lines of 60 characters each may be caused to be printed at each major stage.

EXAMPLE: THIS IS A SAMPLE TRAJECTORY
IDENTIFICATION IS MADE BY REM

Field I	Field III	Field V	Field VI
REM	BCD	$3THIS_bIS_bA_bSAMPLE$	
REM	BCD	$2_bTRAJECTORY$	4
REM	BCD	2IDENTIFICATI	6
REM	BCD	$3\phi N_bIS_bMADE_bBY_bREM$	8

Here, the leading number in Field V is the number of 6 character BCD words on this card (including blanks).*

b. Case Number. For specific identification of each case, the case number is printed at the top of each page.

EXAMPLE: CASE 3.02A4

Field I	Field III	Field V
NCASE	BCD	13.02A4

where, the leading 1 in Field III denotes that one 6-character field is to be read. Only one BCD word is allowable in the program for case number identification.

*This example could be put on one card, but has been segmented here because of page limitations.

c. Required Data Input for Each Case

QTY.	UNITS	SYMBOL	PT	NOM	VALUES	REMARKS
		STCASE		0		Initial card (see also Merge Data)
		NCASE	BCD	0		case number
		REM	BCD	Blanks		Remarks (maximum 30 words)
		NSTAGE	NO	1		Stage number for initiation of problem
t	SEC	TIME	YES	0.		Initial trajectory time
t_{SX}	SEC	TIMSX	YES	0.		Trajectory time at start of stage: i,e., $t_{STAGE} = t - t_{SX}$
t_{max}	SEC	TMAX	YES	0.		Maximum estimated flight time
Δt	SEC	DELTS	YES	.1		Autopilot time interval
		INDATM	NO	1	0	Atmosphere title and computations deleted.
					1	Computes ρ, V_S, T_A, P_A, ν
		PRINT	YES			Print interval
		PRTMIN	YES			Minimum print interval

d. Integration Data

Symbol Used by READ Routine	Math Notation	Symbol used by Integration Routine	Nominal Value	Remarks
IVARBH		IVARBH	0	Use variable step, =1, Use Fixed Step
TIME	t	X	0.	Time to begin integ.
DELTS	Δt	DX	.1	Time internal to int.
AMINER	Δt_{min}	DXMIN	.001	Minimum Δt
AMAXER	Δt_{max}	DXMAX	10000.	Maximum Δt
RELER1	RELER1	RFLER1	.00007	Rel. error tol #1
RELER2	RELER2	RELER2	.000005	Rel. error tol. #2
PRTMIN		PRTMIN	0.	Print Minimum
	TIMER	TIMER	30	Time remaining (sec) before exiting to Plot routine

2. DATA PREPARATION - SUBPROGRAMS

a. Required Data - Option 2 (2SDF)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
m	SLUGS	AMASS	YES	0.		Mass of body
γ	DEG	GAM7D	YES	0.		Elevation flight-path angle
σ	DEG	SIG7D	YES	0.		Horizontal flight-path angle
h	FT	HGC7F	YES	0.		Geodetic altitude
X_{go}	FT	XGZ7F	YES	0.		Origin for longitudinal displacement
Y_{go}	FT	YGZ7F	YES	0.		Origin for horizontal displacement
V_g	FT/SEC	VG77F	YES	0.		Ground referenced velocity
X_g	FT	XG77F	YES	0.		Initial longitudinal displacement
Y_g	FT	YG77F	YES	0.		Initial horizontal displacement
ϕ	DEG	PHIBD	YES	0.		Body Euler angle, roll
ψ	DEG	PSIBD	YES	0.		Body Euler angle, yaw
θ	DEG	THTBD	YES	0.		Body Euler angle, pitch
p	RAD/SEC	PI77R	YES	0.		Inertial roll rate, body axis
q	RAD/SEC	QI77R	YES	0.		Inertial yaw rate, body axis
r	RAD/SEC	RI77R	YES	0.		Inertial pitch rate, body axis
ΔF_x	LBS	DLFXP	YES	0.		Generalized axial force
ΔF_y	LBS	DLFYP	YES	0.		Generalized horizontal force
ΔF_z	LBS	DLFZP	YES	0.		Generalized vertical force
ΔL_T	FTLBS	DLLTF	YES	0.		Generalized rolling moment, body
ΔM_T	FTLBS	DLMTF	YES	0.		Generalized pitching moment, body
ΔN_T	FTLBS	DLNTF	YES	0.		Generalized yawing moment, body
		INDAPC	NO	0	0	Delete α,β print
					1	Print α,β
		INDADD	NO	0	1	Compute and print $\dot{\alpha},\dot{\beta}$
		INDFPA	NO	0	0	Delete print of γ,σ
					1	Print γ,σ
		INDFPR	NO	0	0	Delete $\dot{\gamma},\dot{\sigma}$ calculations
					1	Compute and print $\dot{\gamma},\dot{\sigma}$

Required Data - Option 2 (2SDF) (Contd)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
		INDGCR	NO	0	0	Delete great circle range
					1	Compute and print R_g
		INDPLA	NO	0	0	Delete platform computation
					1	Compute platform angles with platform torqued to local geocentric
=1		INDACM	NO	0	0	Delete accelerometer calculations
					1	Compute and print A_{X_p} A_{Y_p} A_{Z_p} platform accelerometer
					2	Compute and print a_x, a_y, a_z body components of inertial acceleration
≠0						
F_x	LBS	FXB7P	YES	0.		Initial values of summation of forces in body-axes system including body component of weight
F_y	LBS	FYB7P	YES	0.		
F_z	LBS	FZB7P	YES	0.		
		INDGRT	NO	0	0	Delete gimbal rotation Calculations
					1	Compute θ_p, ψ_p, ϕ_p --pitch, yaw, roll
		INDRMC	NO	0	0	Delete rotating machinery computations
					1	Include rotating machinery computations
=1						
ω_r	R.P.M.	OMGRT	YES	0.		Rotational rate of machinery about its own shaft
θ_r	DEG	THTRD	YES	0.		Initial pitch angle of shaft perpendicular to body x-y plane
$\dot{\theta}_r$	RAD/SEC	BTAB01	T1	-		Table of pitch rate of shaft as function of stage time
I_{x_r}	SLUG-FT^2	AIXR7S	YES	0.		Moment of inertia of rotating machinery about its shaft
		INDWGT	NO	0	0	Delete print of weight
					1	Print wt

Required Data - Option 2 (2SDF) (Contd)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
		INDWIN	NO	0	0	Winds are set to zero
					1	Wind velocities specified as f(t)
					2	Wind velocities specified as f(h)
$\neq 0$					3*	Wind velocities specified as $f(R_g)$
$\dot{X}_{gw}$	FT/SEC	WTAB01	T1	-		Table of wind velocity, plus from south to north, f(INDWIN)
$\dot{Y}_{gw}$	FT/SEC	WTAB02	T1	-		Table of wind velocity, plus from west to east, f(INDWIN)
$\dot{Z}_{gw}$	FT/SEC	WTAB03	T1	-		Table of wind velocity, plus from up to downward, f(INDWIN)

NOTE: *requires INDGCR = 1

b. Vehicle Physical Characteristics Subprogram (VPCS)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
		INDVPC*	NO	0	0	Vehicle physical characteristics deleted
					1	Vehicle physical characteristics subprogram used
0						
$x_{c.g.}$	FT	XCGBF	YES	0	-	Longitudinal body C.G. position
$\Delta x_{c.g.}$	FT	DXCGF	YES	0	-	$x_{c.g.} - x_{c.g._{REF}}$
I_{xx}	SLUG-FT^2	AIXXBS	YES	0	-	Moment of inertia about body x axis
I_{yy}	SLUG-FT^2	AIYYBS	YES	0	-	Moment of inertia about body y axis
I_{zz}	SLUG-FT^2	AIZZBS	YES	0	-	Moment of inertia about body z Axis
I_{xy}	SLUG-FT^2	AIXYBS	YES	0	-	Product of inertia, body axes
I_{xz}	SLUG-FT^2	AIXZBS	YES	0	-	Product of inertia, body axes
I_{yz}	SLUG-FT^2	AIYZBS	YES	0	-	Product of inertia, body axes
$\dot{I}_{xx}$	SLUG-FT^2/SEC	AIXXSI	YES	0	-	Rate of change of moment of inertia
$\dot{I}_{yy}$	SLUG-FT^2/SEC	AIYYSI	YES	0	-	Rate of change of moment of inertia
$\dot{I}_{zz}$	SLUG-FT^2/SEC	AIZZSI	YES	0	-	Rate of change of moment of inertia
$\dot{I}_{xy}$	SLUG-FT^2/SEC	AIXYSI	YES	0	-	Rate of change of moment of inertia
$\dot{I}_{xz}$	SLUG-FT^2/SEC	AIXZSI	YES	0	-	Rate of change of moment of inertia
$\dot{I}_{yz}$	SLUG-FT^2/SEC	AIYZSI	YES	0	-	Rate of change of moment of inertia
ℓ_y	FT	ALYJDF	YES	0	-	Characteristic distance for jet damping force
ℓ_z	FT	ALZJDF	YES	0	-	Characteristic distance for jet damping force
ℓ_ℓ	FT	ALLJDF	YES	0	-	Characteristic distance for jet damping force
ℓ_m	FT	ALMJDF	YES	0	-	Characteristic distance for jet damping moment
ℓ_n	FT	ALNJDF	YES	0	-	Characteristic distance for jet damping moment

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
		(INDVPC)			(1)	Vehicle physical characteristics subprogram used to compute vehicle characteristics as f(MASS, TIME, or C.G.). If INDTFF = 0, then INDTSO must be input as 1 to read values below (to INDIDT). Otherwise use INDVPC = 0, input data.
1						
$x_{c.g._{REF}}$	FT	XCGRF	YES	0	-	Reference longitudinal body c.g. position
$x_{c.g.}$	FT	VTAB01	T1	-		Table of c.g. as f(MASS)
I_{xx}	SLUG-FT^2	VTAB02	T1	-		Table of moment of inertia about x axis, f(m)
I_{yy}	SLUG-FT^2	VTAB03	T1	-		Table of moment of inertia about y axis, f(n)
I_{zz}	SLUG-FT^2	VTAB04	T1	-		Table of moment of inertia about z axis, f(m)
		INDXZS	NO	0	0	XZ is not a plane of symmetry
					1	XZ is a plane of symmetry
0						
I_{xy}	SLUG-FT^2	VTAB05	T1	-	-	Table of product of inertia f(m)
I_{yz}	SLUG-FT^2	VTAB07	T1	-	-	Table of product of inertial f(m)
		(INDXZS)			1	XZ is a plane of symmetry $I_{xy} = I_{yz} = 0$
		INDXYS	NO	0	0	XY is not a plane of symmetry
					1	XY is a plane of symmetry
0						
I_{xz}	SLUG-FT^2	VTAB06	T1	-		Table of product of inertia f(m)
		(INDXYS)			1	XY is a plane of symmetry $I_{xz} = 0$
		INDJDP	NO	0	0	Jet damping; $\ell_\ell = \ell_m = \ell_n = \ell_y = \ell_z = 0$
					1	ℓ_ℓ, ℓ_m, ℓ_n, ℓ_y, ℓ_z are computed from tables
1						
ℓ_y	FT	VTAB08	T1	-		Table of characteristic distance for damping force, f($x_{c.g.}$)
ℓ_z	FT	VTAB09	T1	-		Table of characteristic distance for jet damping force, f($x_{c.g.}$)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
ℓ_ℓ	FT	VTAB10	T1	-		Table of characteristic distance for jet damping moment, $f(x_{c.g.})$
ℓ_m	FT	VTAB11	T1	-		Table of characteristic distance for jet damping moment, $f(x_{c.g.})$
ℓ_n	FT	VTAB12	T1	-		Table of characteristic distance for jet damping moment, $f(x_{c.g.})$
		INDIDT	NO	0	0	Inertia derivatives: $\dot{I}_{xx} = \dot{I}_{yy} = \dot{I}_{zz} = \dot{I}_{xy} = \dot{I}_{xz} = \dot{I}_{yz} = 0$
					1	Inertia derivatives are computed from tables
$\dot{I}_{xx}$	SLUG-FT^2/SEC	VTAB13	T1	-		Table of inertia derivative, $f(t_s)$
$\dot{I}_{yy}$	SLUG-FT^2/SEC	VTAB14	T1	-		Table of inertia derivative, $f(t_s)$
$\dot{I}_{zz}$	SLUG-FT^2/SEC	VTAB15	T1	-		Table of inertia derivative, $f(t_s)$
$\dot{I}_{xy}$	SLUG-FT^2/SEC	VTAB16	T1	-		Table of inertia derivative, $f(t_s)$
$\dot{I}_{xz}$	SLUG-FT^2/SEC	VTAB17	T1	-		Table of inertia derivative, $f(t_s)$
$\dot{I}_{yz}$	SLUG-FT^2/SEC	VTAB18	T1	-		Table of inertia derivative, $f(t_s)$
ε_{18}	FT	EPS18	YES	0		Incremental error in $X_{c.g.}$
ε_{19}	SLUG-FT^2	EPS19	YES	0		Incremental error in I_{xx}
ε_{20}	SLUG-FT^2	EPS20	YES	0		Incremental error in I_{yy}
ε_{21}	SLUG-FT^2	EPS21	YES	0		Incremental error in I_{zz}
ε_{22}	SLUG-FT^2	EPS22	YES	0		Incremental error in I_{xy}
ε_{23}	SLUG-FT^2	EPS23	YES	0		Incremental error in I_{xz}
ε_{24}	SLUG-FT^2	EPS24	YES	0		Incremental error in I_{yz}

c. Aerodynamics Subprogram (SACS)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUE	REMARKS
		NDAER	NO	0	0	Delete aerodynamics calculations
					1	Compute aerodynamics for controlled aircraft; moderate variations (options 1-5)
0						
a	LBS	AA77P	YES	0		Axial force (body axis)
y	LBS	YA77P	YES	0		Side force (body axis)
n_f	LBS	ANA77P	YES	0		Normal force (body axis)
ℓ	FT-LBS	ALA77F	YES	0		Moment about body x axis
m	FT-LBS	AMA77F	YES	0		Moment about body y axis
n	FT-LBS	ANAZ7F	YES	0		Moment about body z axis

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
		(INDAER)			1	Compute Aerodynamics for Controlled Aircraft, Moderate Variations
1						
S	FT^2	AREFF	YES	0		Reference area
d_1	FT	D1RFF	YES	0		Reference length, longitudinal
d_2	FT	D2RFF	YES	0		Reference length, lateral
ε_1	-	EPS1	YES	1.		Error multiplier for C_N
ε_2	-	EPS2	YES	0		Incremental error in C_N
ε_3	-	EPS3	YES	1.		Error multiplier for C_A
ε_4	-	EPS4	YES	0		Incremental error in C_A
ε_5	-	EPS5	YES	1.		Error multiplier for C_y
ε_6	-	EPS6	YES	0		Incremental error in C_y
ε_7		EPS7	YES	1.		Error multiplier for C_ℓ
ε_8	-	EPS8	YES	0		Incremental error in C_ℓ
ε_9	-	EPS9	YES	1.		Error multiplier for C_m
ε_{10}	-	EPS10	YES	0		Incremental error in C_m
ε_{11}	-	EPS11	YES	1.		Error multiplier for C_n
ε_{12}	-	EPS12	YES	0		Incremental error in C_n
$h_{aero\ max}$	FT	AMAXH	YES	1.E6		Aerodynamic Cut-Off Altitude: $h > h_{max}$: Aero. = 0 $h \le h_{max}$: $h > 295{,}275$: Constant aero. $h \le 295{,}275$: Compute aero.

Constant Aero (Data must be submitted in body axes system)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
C_A	-	CAMNU	YES	0		Axial force coefficient
C_N	-	CN1MNU	YES	0		Normal force coefficient
C_Y	-	CYMNU	YES	0		Side force coefficient
C_ℓ	-	CLMNU	YES	0		Rolling moment coefficient
C_m	-	CMMNU	YES	0		Pitching moment coefficient
C_n	-	CN2MNU	YES	0		Yawing moment coefficient

QTY.	UNITS	SYMBOL	PT.	NOM. VALUES	REMARKS

The following tables are two-dimensional and are read as functions of Mach number, M_N. The table indicators are nominally zero but must be input as 1 if the table is to be used:

C_{A_α}	PER DEG	ATAB01	T2	-	$\partial C_A/\partial\alpha$
$C_{A_{\alpha^2}}$	PER DEG^2	ATAB02	T2	-	$\partial C_A/\partial\alpha^2$
C_{A_β}	PER DEG	ATAB03	T2	-	$\partial C_A/\partial\beta$
$C_{A_{\beta^2}}$	PER DEG^2	ATAB04	T2	-	$\partial C_A/\partial\beta^2$
$C_{A_{\delta q}}$	PER DEG	ATAB05	T2	-	$\partial C_A/\partial\delta_q$
$C_{A_{\delta q^2}}$	PER DEG^2	ATAB06	T2	-	$\partial C_A/\partial\delta_q^2$
$C_{A\alpha\beta}$	PER DEG^2	ATAB07	T2		$\partial^2 C_A/\partial\alpha\partial\beta$
$C_{A\alpha\delta q}$	PER DEG^2	ATAB08	T2	-	$\partial^2 C_A/\partial\alpha\partial\delta_q$
$C_{A\beta\delta q}$	PER DEG^2	ATAB09	T2	-	$\partial^2 C_A/\partial\beta\partial\delta_q$
C_{N_o}	-	ATAB10	T2	-	C_N AT $\alpha = \beta = 0°$
C_{N_α}	PER DEG	ATAB11	T2	-	$\partial C_N/\partial\alpha$
$C_{N_{\alpha^2}}$	PER DEG^2	ATAB12	T2	-	$\partial C_N/\partial\alpha^2$
C_{N_β}	PER DEG	ATAB13	T2	-	$\partial C_N/\partial\beta$
$C_{N_{\beta^2}}$	PER DEG^2	ATAB14	T2	-	$\partial C_N/\partial\beta^2$
$C_{N_{\delta q}}$	PER DEG	ATAB15	T2	-	$\partial C_N/\partial\delta_q$
$C_{N_{\delta q^2}}$	PER DEG^2	ATAB16	T2		$\partial C_N/\partial\delta_q^2$

QTY.	UNITS	SYMBOL	PT.	NOM. VALUES	REMARKS
$C_{N_{\alpha\beta}}$	PER DEG^2	ATAB17	T2	-	$\partial^2 C_N/\partial\alpha\partial\beta$
$C_{N_{\alpha\delta_q}}$	PER DEG^2	ATAB18	T2	-	$\partial^2 C_N/\partial\alpha\partial\delta_q$
$C_{N_{\beta\delta_q}}$	PER DEG^2	ATAB19	T2	-	$\partial^2 C_N/\partial\beta\partial\delta_q$
$C_{N_{\dot\alpha}}$	PER RAD	ATAB20	T2	-	$\partial C_N/\partial(\dot\alpha d_1/2V_a)$
$C_{N_{\dot\alpha x}}$	PER RAD PER FT	ATAB21	T2	-	$\partial^2 C_N/\partial(\dot\alpha d_1/2V_a)\partial x_{c.g.}$
C_{N_q}	PER RAD	ATAB22	T2	-	$\partial C_N/\partial(qd_1/2V_a)$
$C_{N_{q_x}}$	PER RAD PER FT	ATAB23	T2	-	$\partial^2 C_N/\partial(qd_1/2V_a)\partial x_{c.g.}$
C_{Y_o}	-	ATAB24	T2	-	C_Y AT $\alpha = \beta = 0°$
C_{Y_α}	PER DEG	ATAB25	T2	-	$\partial C_Y/\partial\alpha$
$C_{Y_{\alpha^2}}$	PER DEG^2	ATAB26	T2	-	$\partial C_Y/\partial\alpha^2$
C_{Y_β}	PER DEG	.ATAB27	T2	-	$\partial C_Y/\partial\beta$
$C_{Y_{\beta^2}}$	PER DEG^2	.ATAB28	T2	-	$\partial C_Y/\partial\beta^2$
$C_{Y_{\delta_r}}$	PER DEG	ATAB29	T2	-	$\partial C_Y/\partial\delta_r$
$C_{Y_{\delta_r^2}}$	PER DEG^2	/.TAB30	T2	-	$\partial C_Y/\partial\delta_r^2$
$C_{Y_{\alpha\beta}}$	PER DEG^2	ATAB31	T2	-	$\partial^2 C_Y/\partial\alpha\partial\beta$
$C_{Y_{\alpha\delta_r}}$	PER DEG^2	ATAB32	T2	-	$\partial^2 C_Y/\partial\alpha\partial\delta_r$
$C_{Y_{\beta\delta_r}}$	PER DEG^2	ATAB33	T2	-	$\partial^2 C_Y/\partial\beta\partial\delta_r$
$C_{Y_{\dot\beta}}$	PER RAD	ATAB34	T2	-	$\partial C_Y/\partial(\dot\beta d_2/2V_a)$
$C_{Y_{\dot\beta x}}$	PER RAD PER FT	ATAB35	T2	-	$\partial^2 C_Y/\partial(\dot\beta d_2/2V_a)\partial x_{c.g.}$

QTY.	UNITS	SYMBOL	PT.	NOM. VALUES	REMARKS
C_{y_r}	PER RAD	ATAB36	T2	-	$\partial C_y/\partial(rd_2/2V_a)$
$C_{y_{rx}}$	PER RAD PER FT	ATAB37	T2	-	$\partial^2 C_y/\partial(rd_2/2V_a)\partial x_{c.g.}$
C_{ℓ_o}	-	ATAB38	T2	-	C_ℓ AT $\alpha = \beta = 0°$
C_{ℓ_α}	PER DEG	ATAB39	T2	-	$\partial C_\ell/\partial\alpha$
$C_{\ell_{\alpha^2}}$	PER DEG^2	ATAB40	T2	-	$\partial C_\ell/\partial\alpha^2$
C_{ℓ_β}	PER DEG	ATAB41	T2	-	$\partial C_\ell/\partial\beta$
$C_{\ell_{\beta^2}}$	PER DEG^2	ATAB42	T2	-	$\partial C_\ell/\partial\beta^2$
$C_{\ell_{\delta_p}}$	PER DEG	.ATAB43	T2	-	$\partial C_\ell/\partial\delta_p$
$C_{\ell_{\delta_p^2}}$	PER DEG^2	.ATAB44	T2	-	$\partial C_\ell/\partial\delta_p^2$
$C_{\ell_{\alpha\beta}}$	PER DEG^2	ATAB45	T2	-	$\partial^2 C_\ell/\partial\alpha\partial\beta$
$C_{\ell_{\alpha\delta_p}}$	PER DEG^2	ATAB46	T2	-	$\partial^2 C_\ell/\partial\alpha\partial\delta_p$
$C_{\ell_{\beta\delta p}}$	PER DEG^2	ATAB47	T2	-	$\partial^2 C_\ell/\partial\beta\partial\delta_p$
C_{ℓ_p}	PER RAD	.ATAB48	T2	-	$\partial C_\ell/\partial(pd_2/2V_a)$
C_{ℓ_r}	PER RAD	ATAB49	T2	-	$\partial C_\ell/\partial(rd_2/2V_a)$
$C_{\ell_{rx}}$	PER RAD PER FT	ATAB50	T2	-	$\partial^2 C_\ell/\partial(rd_2/2V_a)\partial\, x_{c.g.}$
C_{m_o}	-	.ATAB51	T2	-	C_m AT $\alpha = \beta = 0°$
C_{m_α}	PER DEG	.ATAB52	T2	-	$\partial C_m/\partial\alpha$
$C_{m_{\alpha^2}}$	PER DEG^2	.ATAB53	T2	-	$\partial C_m/\partial\alpha^2$
C_{m_β}	PER DEG	ATAB54	T2	-	$\partial C_m/\partial\beta$
$C_{m_{\beta^2}}$	PER DEG^2	ATAB55	T2	-	$\partial C_m/\partial\beta^2$

QTY.	UNITS	SYMBOL	PT.	NOM. VALUES	REMARKS
$C_{m_{\delta q}}$	PER DEG	.ATAB56	T2	-	$\partial C_m/\partial \delta_q$
$C_{m_{\delta q}2}$	PER DEG^2	.ATAB57	T2	-	$\partial C_m/\partial \delta_q^2$
$C_{m_{\alpha\beta}}$	PER DEG^2	ATAB58	T2	-	$\partial^2 C_m/\partial\alpha\partial\beta$
$C_{m_{\alpha\delta q}}$	PER DEG^2	ATAB59	T2	-	$\partial^2 C_m/\partial\alpha\partial\delta_q$
$C_{m_{\beta\delta q}}$	PER DEG^2	ATAB60	T2	-	$\partial^2 C_m/\partial\beta\partial\delta_q$
$C_{m_{\dot\alpha}}$	PER RAD	.ATAB61	T2	-	$\partial C_m/\partial(\dot\alpha d_1/2V_a)$
$C_{m_{\dot\alpha_x}}$	PER RAD PER FT	ATAB62	T2	-	$\partial^2 C_m/\partial(\dot\alpha d_1/2V_a)\partial x_{c.g.}$
C_{m_q}	PER RAD	.ATAB63	T2	-	$\partial C_m/\partial(qd_1/2V_a)$
$C_{m_{q_x}}$	PER RAD PER FT	ATAB64	T2	-	$\partial^2 C_m/\partial(qd_1/2V_a)\partial x_{c.g.}$
C_{n_o}	-	ATAB65	T2	-	C_n AT $\alpha = \beta = 0°$
C_{n_α}	PER DEG	ATAB66	T2	-	$\partial C_n/\partial\alpha$
$C_{n_\alpha 2}$	PER DEG^2	ATAB67	T2	-	$\partial C_n/\partial\alpha^2$
C_{n_β}	PER DEG	.ATAB68	T2	-	$\partial C_n/\partial\beta$
$C_{n_\beta 2}$	PER DEG^2	.ATAB69	T2	-	$\partial C_n/\partial\beta^2$
$C_{n_{\delta r}}$	PER DEG	.ATAB70	T2	-	$\partial C_n/\partial\delta_r$
$C_{n_{\delta r}^2}$	PER DEG^2	.ATAB71	T2	-	$\partial C_n/\partial\delta_r^2$
$C_{n_{\alpha\beta}}$	PER DEG^2	ATAB72	T2	-	$\partial^2 C_n/\partial\alpha\partial\beta$
$C_{n_{\alpha\delta r}}$	PER DEG^2	ATAB73	T2	-	$\partial^2 C_n/\partial\alpha\partial\delta_r$
$C_{n_{\beta\delta r}}$	PER DEG^2	ATAB74	T2	-	$\partial^2 C_n/\partial\beta\partial\delta_r$
$C_{n_{\dot\beta}}$	PER RAD	ATAB75	T2	-	$\partial C_n/\partial(\dot\beta d_2/2V_a)$

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
$C_{n_{\dot{\beta}x}}$	PER RAD PER FT	ATAB76	T2	-		$\partial^2 C_n/\partial(\dot{\beta}d_2/2V_a)\partial x_{c.g.}$
C_{n_r}	PER RAD	.ATAB77	T2	-		$\partial C_n/\partial(rd_2/2V_a)$
$C_{n_{r_x}}$	PER RAD PER FT	ATAB78	T2	-		$\partial^2 C_n/\partial(rd_2/2V_a)\partial x_{c.g.}$
		INDA80	NO	0	0	Table not used
					1	Table used
1 C_{A_o}	-	.ATAB80	T3	-		C_A AT $\alpha = \beta = 0°$

d. Thrust Subprogram (TFFS)

QTY.	UNITS	SYMBOL	PT.	NOM.	VALUES	REMARKS
		INDTFF	NO	0	0	Thrust subprogram deleted. Required for flight plan Programmer 1 in which case no additional thrust subprogram data should be input.
					3	Airbreathing engine
0						
		INDTSO	NO	0	0	
					1	Converts engine thrust to necessary axes systems
		(INDTSO)		0	0	Deletes thrust conversion to body axes
0						
L_T	FT-LBS	ALT77F	YES	0		Engine roll moment, body axis
M_T	FT-LBS	AMT77F	YES	0		Engine pitch moment, body axis
N_T	FT-LBS	ANT77F	YES	0		Engine yaw moment, body axis
T_X	LBS	TXB7P	YES	0		Longitudinal thrust component, body axis
T_y	LBS	TYB7P	YES	0		Lateral thrust component, body axis
T_z	LBS	TZB7P	YES	0		Vertical thrust component, body axis
0						
Z_N(in)	FT	ZN	YES	0		
Y_N(IN)	FT	YN	YES	0		
=3		(INDTFF)			3	Airbreathing engine
T	LBS	TTAB10	T5	-		Engine thrust as $f(M_N, N)$
		IT10W	NO	0	5	Number of values of N of TTAB10
		IT10X	NO	0		Number of values of M_N for TTAB10
N(IN)	-	N	YES	0		Throttle setting

3. DATA PREPARATION - STAGING

a. Staging

For a trajectory computation which requires a change in program computation and/or a change in data for computations, staging steps are used.

Stage Test. Termination of a stage is accomplished with the following input data:

	Field I	Field III	Field V
	AINCRS	BCD	nBBBBB CCCC
	STEST		X.X, YYY.
and/or			
	DECRES	BCD	nBBBB
	STESTD		X.X
		TRA	

where

n = number of BCD words which are symbolic in the directory (maximum of 4 parameters which cannot be exceeded (AINCRS) and 4 which cannot be less than (DECRES).

$\left.\begin{array}{l}\text{BBBBB}\\ \text{CCC}\end{array}\right\}$ = BCD word symbols of variables computed in program

$\left.\begin{array}{l}\text{X.X}\\ \text{YYY.}\end{array}\right\}$ = values of variables

A stage requires two sets of data, each followed by a TRA card.

Primary data

FIELD I	FIELD III	FIELD V	
INDSTR		0	nominal
		1	Reset the stage time to zero and update the stage number by one
INDSP		-N	
	TRA		

where

INDSP = indicator for subprogram to be added or changed from previous stage.

N = fixed point integer value of indicator desired for stage and must be input as negative for proper initialization.

Secondary data

Any data required by added or changed subprograms, any data to be changed from preceding stage data, or any changes in auxiliary computations, are added followed by stage test data and a TRA card.

Final Stage. If a particular stage is to be the last or final stage of a problem, a final stage indicator is required prior to the final TRA card.

FIELD I	FIELD V
INDSTF	1

b. Directory-Symbols Available for Staging

In order to stage on a given variable, the symbol for this variable must be contained in the program directory. Below is a list of variables presently available for staging. They are listed alphabetically by symbol name. For a complete listing of the directory, consult the program listings. Values listed as "not used" are not calculated in this version of the program.

SYMBOL	QUANTITY	UNITS	REMARKS
AA77P	a	lbs	Axial force, body axis.
AIXXBS	I_{xx}	slug-ft^2	Moment of inertia, body x axis.
AIXXS1	$\dot{I}_{xx}$	slug-ft^2/sec	Rate of change of moment of inertia.
AIXYBS	I_{xy}	slug-ft^2	Product of inertia, body axes
AIXYS1	$\dot{I}_{xy}$	slug-ft^2/sec	Rate of change of product of inertia.
AIXZBS	I_{xz}	slug-ft^2	Product of inertia body axes.
AIXZS1	$\dot{I}_{xz}$	slug-ft^2/sec	Rate of change of product of inertia.
AIYYBS	I_{yy}	slug-ft^2	Moment of inertia, body y axis.
AIYYS1	$\dot{I}_{yy}$	slug-ft^2/sec	Rate of change of moment of inertia.
AIYZBS	I_{yz}	slug-ft^2	Product of inertia, body axes.
AIYZS1	$\dot{I}_{yz}$	slug-ft^2/sec	Rate of change of product of inertia.
AIZZBS	I_{zz}	slug-ft^2	Moment of inertia, body y axis.
AIZZS1	$\dot{I}_{zz}$	slug-ft^2/sec	Rate of change of moment of inertia.
ALAMTD	λ_T	deg	Thrust swivel angle. (Not used)
ALA77F	ℓ	ft-lbs	Moment about body x axis, aerodynamic
ALB77F	L	ft-lbs	Moment about body x axis, total.
ALIFTP	L	lbs	Lift force wind axis.
ALPHD	α	deg	Angle of attack.
ALPHR1	$\dot{\alpha}$	rad/sec	Rate of change of angle of attack

SYMBOL	QUANTITY	UNITS	REMARKS
ALPTD	α_T	deg	Total angle of attack. (Not used)
ALT77F	L_T	ft-lbs	Engine roll moment, body axis.
AMACH	M_N	-	Mach number.
AMASFS	m_f	slugs	Fuel mass consumed. (Not used)
AMASF1	$\dot{m}_f$	slugs/sec	Rate of change of fuel mass. (Not used)
AMASS	m	slugs	Mass
AMASS1	$\dot{m}$	slugs/sec	Rate of change of mass.
AMA77F	m	ft-lbs	Moment about body y axis, aerodynamic.
AMB77F	M	ft-lbs	Moment about body y axis, total.
AMT77F	M_T	ft-lbs	Engine pitch moment, body axis.
ANAB7G	n_a	g's	Axial load factor, body axis. (Not used)
ANAZ7F	n	ft-lbs	Moment about body z axis, aerodynamic.
ANA77P	N_F	lbs	Normal force, body axes.
ANB77F	N	ft-lbs	Moment about body z axis, total.
ANGAMG	n_γ	g's	Vertical load factor, wind axis. (Not used)
ANPSIG	n_ψ	g's	Side load factor, body axis. (Not used)
ANSIGG	n_σ	g's	Side load factor, wind axis. (Not used)
ANTHTG	n_θ	g's	Vertical load factor, body axis. (Not used)
ANT77F	N_T	ft-lbs	Engine yaw moment, body axis.
ANUA7F	ν	ft^2/sec	Kinematic viscosity of atmosphere.
ANVW7G	n_v	g's	Axial load factor, wind axis. (Not used)
AXP7F	A_{x_p}	ft/sec^2	Platform acceleration, x direction.
AX77F	a_x	ft/sec^2	Body component of inertial acceleration.

SYMBOL	QUANTITY	UNITS	REMARKS
AYP7F	A_{Y_p}	ft/sec^2	Platform acceleration, z direction.
AY77F	a_y	ft/sec^2	Body component of inertial acceleration.
AZP7F	A_{z_p}	ft/sec^2	Platform acceleration, z direction
AZ77D	a_z	ft/sec^2	Body component of inertial acceleration.
BA77D	B_A	deg	Bank angle. (Not used)
BETAD	β	deg	Angle of sideslip.
BETAR1	$\dot{\beta}$	rad/sec	Rate of change of sideslip angle.
BI77D	B	deg	Equatorial angle between geocentric and inertial coordinate systems. (Not used)
BP77D	B_p	deg	Equatorial angle between inertial and platform coordinates. (Not used)
CA	C_A	-	Axial force coefficient.
CALPG	C_α	rad/g	Gain factor for angle of attack. (Not used)
CBETG	C_β	rad/g	Gain factor for angle of sideslip. (Not used)
CD	C_D	-	Drag coefficient.
CGAMG	C_γ	-	Gain factor for flight path angle. (Not used)
CL	C_L	-	Lift coefficient.
CM	C_m	-	Pitching moment coefficient.
CN	C_N	-	Normal force coefficient.
CP	C_p	-	Pressure coefficient. (Not used)
CRM	C_ℓ	-	Rolling moment coefficient.
CY	C_Y	-	Side force coefficient, wind axis.
CYA	C_y	-	Side force coefficient, body axis.
CYM	C_n	-	Yawing moment coefficient.

SYMBOL	QUANTITY	UNITS	REMARKS
DELPD	δ_p	deg	Control deflection to induce a moment about the x axis.
DELQD	δ_q	deg	Control deflection to induce a moment about the y axis.
DELRD	δ_r	deg	Control deflection to induce a moment about the z axis.
DLFXP	ΔF_x	lb	Generalized axial force.
DLFYP	ΔF_y	lbs	Generalized horizontal force.
DLFZP	ΔF_z	lbs	Generalized vertical force.
DLLTF	ΔL_T	ft-lb	Generalized rolling moment, body axis.
DLMTF	ΔM_T	ft-lb	Generalized pitching moment, body axis.
DLNTF	ΔN_T	ft-lb	Generalized yawing moment, body axis
DRAGP	D	lbs	Drag force, wind axis
DTC2R	$\Delta\theta_{C_2}$	rad	Pitch attitude command correction due to temperature and temperature rate. (Not used)
DXCGF	ΔX_{cg}	ft	$X_{cg}-X_{cg_{ref}}$
DYNPP	q^*	lbs/ft^2	Dynamic pressure.
DYNPP1	$\dot{q}^*$	lbs/ft^2sec	Rate of change of dynamic pressure.
FXB7P	F_x	lbs	Summation of force components, body x axis.
FXE7P	F_{x_e}	lbs	Summation of force components, planet X_e axis. (Not used)
FYB7P	F_y	lbs	Summation of force components, body y axis.
FYE7P	F_{y_e}	lbs	Summation of force components, planet Y_e axis. (Not Used)
FZB7P	F_z	lbs	Summation of force components, body z axis.

SYMBOL	QUANTITY	UNITS	REMARKS
FZE7P	F_{z_e}	lbs	Summation of force components, planet Z_e axis. (Not used)
GAMDD	γ_D	deg	Geodetic elevation flight path angle. (Not used)
GAM7D	γ	deg	Elevation flight path angle.
GXB7F	g_x	ft/sec^2	Gravity component, body x axis.
GXE7F	g_{X_e}	ft/sec^2	Gravity component, earth X_e earth X_e axis. (Not used)
GXG7F	g_{X_g}	ft/sec^2	Gravity component, geocentric horizon coordinate.
GXI7F	g_{X_I}	ft/sec^2	Gravity component, inertial X axis.
GYB7F	g_y	ft/sec^2	Gravity component, body y axis.
GYE7F	g_{Y_e}	ft/sec^2	Gravity component, earth Y_e axis. (Not used)
GYI7F	g_{Y_I}	ft/sec^2	Gravity component, inertial Y axis.
GZB7F	g_z	ft/sec^2	Gravity component, body z axis.
GZE7F	g_{Z_e}	ft/sec^2	Gravity component, earth Z_e axis. (Not used)
GZG7F	g_z	ft/sec^2	Gravity component, geocentric coordinate.
GZI7F	g_{Z_I}	ft/sec^2	Gravity component, inertial Z axis.
HGC7F	h	ft	Geodetic altitude.
OMXGR	ω_{X_g}	rad/sec	X_g component of planet rotation rate. (Not used)
OMZGR	ω_{Z_g}	rad/sec	Z_g component of planet rotation rate. (Not used)
PA77P	P	lbs/ft^2	Atmospheric pressure.
PHIAD	ϕ_A	deg	Aerodynamic roll angle. (Not used)
PHIBD	ϕ	deg	Body Euler angle, roll.

SYMBOL	QUANTITY	UNITS	REMARKS
PHIGD	ϕ_g	deg	Geodetic latitude. (Not used)
PHILD	ϕ_L	deg	Geocentric latitude. (Not used)
PHIPD	ϕ_p	deg	Angle between body axis and platform axis.
PHITD	ϕ_T	deg	Rotation angle of plane of thrust swivel. (Not used)
PI77R	p	rad/sec	Inertial angular rate of body about x axis.
PI77R1	$\dot{p}$	rad/sec^2	Rate of change of p.
PSIBD	ψ	deg	Body Euler angle, yaw.
PSIPD	ψ_p	deg	Angle between body axis and platform axis.
QA77D	q_A	deg/sec	Aeroelastic body-bending angular rate. (Not used)
QI77R	q	rad/sec	Inertial angular rate of body about y axis.
QI77R1	$\dot{q}$	rad/sec^2	Rate of change of q.
RA77D	r_A	deg/sec	Aeroelastic body-bending angular rate. (Not used)
RD77N	R_D	n.mi.	Total distance traveled over planet surface. (Not used)
RG77N	R_g	n.mi.	Great circle range.
RHOAS	ρ	slugs/ft^3	Atmospheric density.
RI77R	r	rad/sec	Inertial angular rate of body about z axis.
RI77R1	$\dot{r}$	rad/sec^2	Rate of change of r.
RPHLF	R_{ϕ_L}	ft	Local planet radius. (Not used)
R777F	R	ft	Distance from center of planet to body.
SIDEP	Y	lb	Side force, wind axis.

SYMBOL	QUANTITY	UNITS	REMARKS
SIGDD	σ_D	deg	Geodetic horizontal flight-path angle. (Not used)
SIG7D	σ	deg	Horizontal flight path angle.
SIG7R1	$\dot{\sigma}$	rad/sec	Rate of change of horizontal flight path angle.
TA77R	T	°R	Temperature of the atmosphere.
TE77P	T	lbs	Engine thrust.
THL7D	θ_L	deg	Longitude. (Not used)
THTBD	θ	deg	Body Euler angle, pitch.
THTPD	θ_p	deg	Angle between body and platform axis.
THTRD	θ_r	deg	Pitch angle between rotating machinery axis and platform axis.
TIME	t	sec	Flight time.
TIMES	t_s	sec	Stage time.
TSTGR	T_e	°R	Equilibrium stagnation temperature. (Not used)
TSTGR1	$\dot{T}_e$	°R/sec	Equilibrium stagnation temperature rate. (Not used)
TS77R	T_s	°R	Skin temperature. (Not used)
TS77R1	$\dot{T}_s$	°R/sec	Rate of change of skin temperature. (Not used)
TVACP	T_{vac}	lbs	Vacuum thrust.
TXA7P	T_{X_A}	lbs	Longitudinal thrust component, wind axis.
TXB7P	T_X	lbs	Longitudinal thrust component, body axis.
TXE7P	T_{X_e}	lbs	Longitudinal thrust component, planet X_e axis. (Not used)
TYA7P	T_{Y_A}	lbs	Lateral thrust component, wind axis.

SYMBOL	QUANTITY	UNITS	REMARKS
TYB7P	T_Y	lbs	Lateral thrust component, body axis.
TYE7P	T_{Y_e}	lbs	Lateral thrust component, planet Y_e axis. (Not used)
TZA7P	T_{Z_A}	lbs	Vertical thrust component, wind axis.
TZB7P	T_Z	lbs	Vertical thrust component, body axis.
TZE7P	T_{Z_e}	lbs	Vertical thrust component, planet Z_e axis. (Not used)
U777F	u	ft/sec	Inertial velocity component, body x axis.
U777F1	$\dot{u}$	ft/sec^2	Rate of change of u component of velocity.
VA77F	V_A	ft/sec	Airspeed.
VD77F	V_D	ft/sec	Velocity decrement due to drag. (Not used)
VGRVF	V_{grav}	ft/sec	Velocity decrement due to gravity. (Not used)
VG77F	V_g	ft/sec	Ground referenced speed.
VI77F	V	ft/sec	Inertial velocity.
VP77F	V_P	ft/sec	Velocity decrement due to rocket nozzle back pressure. (Not used)
VS77F	V_s	ft/sec	Local speed of sound.
VTHEF	V_{THEO}	ft/sec	Theoretical velocity increment due to T_{VAC}. (Not used)
V777F	v	ft/sec	Inertial velocity component, body y axis.
V777F1	$\dot{v}$	ft/sec^2	Rate of change of v component of velocity.
WTR7P	W_t	lb	Weight of vehicle.
W777F	w	ft/sec	Inertial velocity component, body z axis.

SYMBOL	QUANTITY	UNITS	REMARKS
W777FI	$\dot{w}$	ft/sec^2	Rate of change of w component of velocity.
XCGBF	X_{cg}	ft	Longitudinal body center-of-gravity position.
XD77D	X_D	deg	Great circle downrange. (Not used)
XD77N	X_D	n.mi.	Great circle downrange. (Not used)
XE77F	X_e	ft	Planet referenced coordinate. (Not used)
XGW7FI	$\dot{X}_{gw}$	ft/sec	North-south wind velocity.
XG77F	X_g	ft	Local geocentric displacement.
XI77F	X	ft	Inertial coordinate.
YA77P	y	lbs	Side force, body axis.
YD77D	Y_D	deg	Great circle crossrange. (Not used)
YD77N	Y_D	n.mi	Great circle crossrange. (Not used)
YE77F	Y_e	ft	Planet referenced coordinate. (Not used)
YGW7FI	$\dot{Y}_{gw}$	ft/sec	East-west wind velocity.
YG77F	Y_g	ft	Local geocentric displacement.
YI77F	Y	ft	Inertial coordinate.
ZE77F	Z_e	ft	Planet referenced coordinate. (Not used)
ZGW7FI	$\dot{Z}_{gw}$	ft/sec	Vertical wind velocity.
ZG77F	Z_g	ft	Local geocentric displacement.
ZI77F	Z	ft	Inertial coordinate.

4. DATA PREPARATION - DATA MERGING

To eliminate reproducing a large number of cards for successive cases with similar input data, a data merge of a "base" case and a succeeding case or cases can be made. A "base" case is a complete set of input data. A "merge" case is data which differs from the "base" case. Control of this merging facility is controlled by the "STCASE" or start case card.

The STCASE Card

The first card of each case must be the STCASE card. This card has the same fields as the general card format and has the following meanings:

Field I	Field II	Field III	Meaning
STCASE			Execute this case as a base case.
STCASE		NOXEQ	This case is a base case, but no computation of it is desired.
STCASE	MRG		This case is to be merged with the last base case which has preceded it.
STCASE	MRG	NOXEQ	This is a merge case, but is not to be executed. This set-up should be used, since physically removing data cards will accomplish the same function.

In order to illustrate the use of the data merge, a sample case could be set up as:

BASE CASE

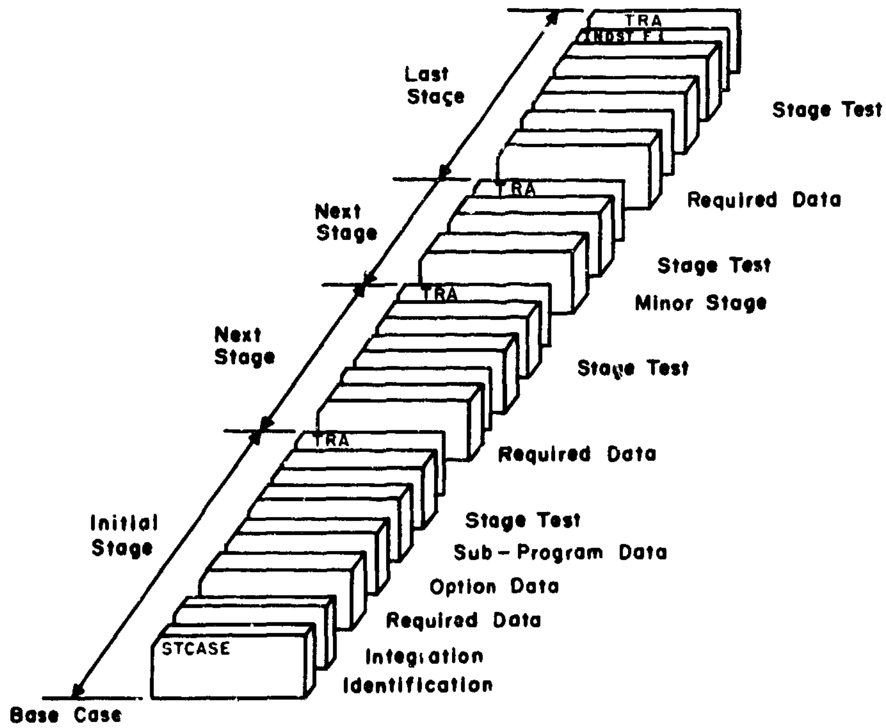
	Field I	II	III
	STCASE		
First Stage	(data)		
		TRA	
Next Stage	(data)		
		TRA	
Last Stage			
	INDSTF		1
		TRA	

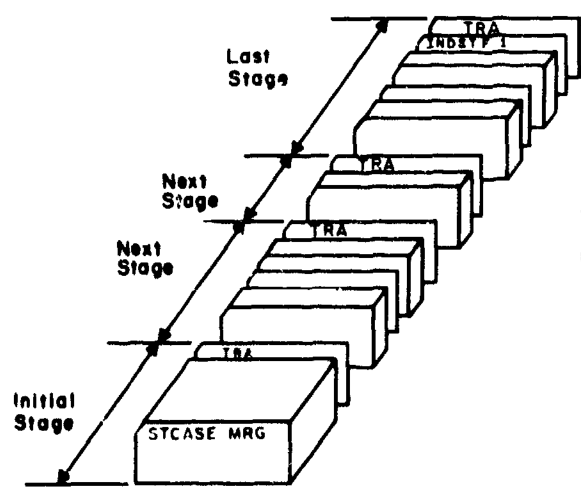
MERGED CASE

Field I	II	III
STCASE	MRG	
	Input differs from base case	
	TRA	
	Input differs from base case	
	TRA	
INDSTF		1
	TRA	

Note that there is a one-to-one correspondence of TRA cards between the base and its merged case. The cards of the merged case would follow directly behind the base case. Succeeding merge cases will use the last preceding base case. Any combination of base and merge cases, regardless of execution or no execution, may be run on a given job. The final stage of both the base case and each succeeding merge case must contain the INDSTF card. A merge case may contain any number of stages irrespective of the number of stages in the base case. However, there must be a one-to-one correspondence of stages up to the point of departure.

PROFILE OF INPUT DATA CARDS FOR BASE CASE AND MERGE CASE





All cards except those marked are input data different than above base case.

MERGE CASE
(To Follow Base Case)

SECTION V

INPUT

The data deck setup will be explained in the order that the deck actually appears. A typical data deck input is shown; however, depending on the kind of problem, all the data shown here may not be required. This will be explained later.

1. BASIC SDF-2 DATA

Column:	1	8	12
	$DATA		
	STCASE	TAB	
	ATAB01		2
	ATAB02		2
	ATAB10		2
	ATAB11		2
	ATAB12		2
	ATAB15		2
	ATAB16		2
	ATAB27		2
	ATAB28		2
	ATAB43		2
	ATAB44		2
	ATAB48		2
	ATAB51		2
	ATAB52		2
	ATAB53		2
	ATAB56		2
	ATAB57		2
	ATAB61		2
	ATAB63		2
	ATAB68		2
	ATAB69		2
	ATAB70		2
	ATAB71		2
	ATAB77		2
	ATAB80		2
	TTAB10		29
	VTAB01		5
	VTAB02		5
	VTAB03		5
	VTAB04		5
	VTAB06		5
	FTAB02		5
	FTAB03		50
	CTAB01		17
	CTAB02		17
	CTAB03		17
	CTAB04		17
	WTAB01		11
	WTAB02		11
	WTAB03		11
	FTAB01		90
		TRA	

The STCASE TAB card (note columns) indicates the beginning of the data deck. This card indicates that all tables used by the program will now be sized. This is followed by cards indicating the tables names and sizes. There are basically five kinds of tables that must be sized: aerodynamics, thrust, vehicle physical properties, wind tables, and landing mod tables. There are 80 possible aerodynamics tables named ATAB01 - ATAB80. The relationship between the table name and a particular aerodynamic coefficient is shown on pages 26-30. Only those tables actually used need to be sized. Because of the assumptions made in Reference 1 (pgs 146, 224-225), each aerodynamic table has a size of two. The thrust table is TTAB10. Because of the assumptions made in Reference 1, thrust table has only two independent variables (i.e., throttle setting and Mach number). There are seven possible vehicle physical properties tables named VTAB01 - VTAB07 (see pgs 21-22). There are three landing mod tables named FTAB01, FTAB02, FTAB03. FTAB01 is the force-deflection curve (i.e., $f_k(\delta_k)$, pg 99, Reference 1) for a single tire. There is an option to use an equation for the force-deflection curve in which case FTAB01 is not needed. FTAB02 is the runway perturbation table (i.e., $\varepsilon(X_{Rk})$, pg 110, Reference 1). FTAB03 is the tire-runway coefficient of friction table (i.e, μ_k, pgs 99-100, Reference 1). The CTAB01-CTAB04 tables are for the strut orifice coefficients (see Paragraph 2, Landing Gear Modification Data). The last card indicating a table name and size is followed by a TRA card (see pg 13). The table-size cards between the STCASE TAB and TRA cards can have any order.

Column: 1	8	12
STCASE		
REM	BCD	3SDF2-GEAR-MOD
NCASE	BCD	1G-MOD
IVARBH		0
TMAX		100.
AMINER		.00005
PRTMIN		.02
AMAXER		.1
DFLTS		.1
PRINT		.1
AMASS		19762.852
HGC7F		120.824
THTBD		3.5896
GAM7D		-3.
VG77F		220.
RWHGR		0.
INDAPC		1
INDADD		1
INDEPA		1
INDPLA		1
INDACM		2
INDGRT		1
INDWGT		1
INDVPC		1
XCGRF		0.
VTAB01		2,0.,1.67,20000.,1.67
VTAB02		2,0.,31.8E+06,20000.,31.8E+06
VTAB03		2,0.,29.4E+06,20000.,29.4E+06
VTAB04		2,0.,57.0E+06,20000.,57.0E+06
INDXZS		1
VTAB06		2,0.,2.39E+06,20000.,2.39E+06

The STCASE, REM, and NCASE cards are discussed on pgs 14 and 15.

The next seven cards from IVARBH to PRINT contain integration information. IVARBH must have a zero value. TMAX is the maximum time span (in seconds) expected for a particular calculation. If the actual time variable in the program exceeds TMAX, the problem will stop. AMINER is the minimum integration interval allowed by the variable step Runge-Kutta (VSRK) integration technique. It is wise to set AMINER to a very small value to allow the VSRK the flexibility to pick as small an integration interval as it needs. There is no need to "second guess" a reasonable value for AMINER and run the risk of picking a value too large.

The data on the next four cards PRTMIN, AMAXER, DELTS, PRINT must-repeat must-conform to the following relationship:

$$PRTMIN \leq AMAXER \leq DELTS \leq PRINT.$$

PRINT is the output print interval. DELTS is the time interval at which all autopilot calculations are updated (that is, so far as the VSRK integration technique is concerned, all control variables remain constant for the time interval DELTS). AMAXER is the maximum integration interval allowed by the VSRK integration technique. PRTMIN is the lower bound on the output print interval. Data output on a PRTMIN condition will only occur when the VSRK has picked an integration interval smaller than PRTMIN and remains at this integration interval long enough for the time span to exceed PRTMIN. Output on a PRTMIN condition is an indication that the data is changing rapidly. The PRTMIN option was added primarily to output the landing gear data at a sufficient frequency to see the detail gear response. If PRTMIN is given a small value (i.e., 0.01 sec, etc.) one must be willing to accept a large volume of data output. When PRTMIN is made zero, data output will only occur at the PRINT interval.

The cards beginning with AMASS down to and including INDWGT are required data for the original SDF-2 Option (see pages 17-19). All input data on those pages is applicable except the following:

1) INDADD must have the value 1
2) INDPLA must have the value 1
3) INDACM must have the value 2
4) INDGRT must have the value 1

The cards beginning with INDVPC and ending with VTAB06 are the vehicle physical properties (see pgs 20-23). INDVPC must have the value 1. Data format for the VTAB tables is shown on pg 8. Since Reference 1, pg 146, makes the assumption of constant mass, only two data points are needed in each of the VTAB tables. RWHGR is an added input and represents runway altitude (ft).

Column: 1	12
INDAER	1
AREFF	6200.
DIRFF	30.9
D2RFF	219.
INDA01	1
ATAB01	.0065,.00748
INDA02	1
ATAB02	.437E-3,.542E-3
INDA10	1
ATAB10	1.34,1.12
INDA11	1
ATAB11	.1112,.1038
INDA12	1
ATAB12	-.224E-2,-.1263E-2
INDA15	1
ATAB15	-.00746,-.00819
INDA16	1
ATAB16	.000142,.000158
INDA27	1
ATAB27	-.0236,-.0236
INDA28	1
ATAB28	.267E-3,.267E-3
INDA43	1
ATAB43	.230E-3,.230E-3
INDA44	1
ATAB44	.212E-4,.212E-4
INDA48	1
ATAB48	-.45,-.45
INDA51	1
ATAB51	.0439,.2439
INDA52	1
ATAB52	-.0312,-.0241
INDA53	1
ATAB53	.630E-3,.293E-3
INDA56	1
ATAB56	.0315,.0346
INDA57	1
ATAB57	-.6E-3,-.667E-3
INDA61	1
ATAB61	-8.,-8.
INDA63	1
ATAB63	-24.,-24.
INDA68	1
ATAB68	.182E-2,.182E-2
INDA69	1
ATAB69	.101E-3,.101E-3
INDA70	1
ATAB70	.158E-2,.158E-2

Column:	1	12
	INDA71	1
	ATAB71	-.346E-5,-.346E-5
	INDA77	1
	ATAB77	-.323,-.323
	INDA80	1
	ATAB80	.139,.155

The next series of cards beginning with INDAER and ending with ATAB80 contain aerodynamic data. INDAER may have one of two values. A zero value deletes the aerodynamics calculations (note that no aerodynamic data is needed here). The only place this option would have value is in the study of vehicle impact where there is no atmosphere. A one value for INDAER causes the aerodynamic calculations to be made. Pages 24-30 show the possible aerodynamic input data. Figure 8 of Reference 1, specifically the block entitled "Summation of Aerodynamic Forces and Moment Coefficients," shows the form of the aerodynamic coefficient equations. Due to the requirements of the autopilot (see Reference 1, pgs 224-225), input data for the C_A and C_N coefficients must be the C_D and C_L coefficients, respectively, in the pseudo wind axes system. The C_y, C_ℓ, C_m, C_n coefficients must be body axis data. As discussed in Reference 1 (pg 225), only two data points are needed for each aerodynamic table used, the first data point is for full ground effect and the second is for no ground effect.

Column:	1	12	67
	INDTFF	3	
	INDTSO	1	
	IT10W	5	
	IT10X	4	
	TTAB10	-2.,-1.,0.,1.,2.	
	TTAB10	0.,.1,.2,.3	6
	TTAB10	-13000.,-800.,0.,2200.,37400.	10
	TTAB10	-20500.,-3400.,-900.,1300.,34600.	15
	TTAB10	-30500.,-7500.,-1700.,500.,31600.	20
	TTAB10	-4300.,-14300.,-2600.,-400.,28400.	25

The next series of cards beginning with INDTFF and ending with the last TTAB10 card pertain to engine thrust data. The indicator INDTFF must (see Section IV para 3b for exception) have the value 3. INDTSO should always have a one value (see pgs 21 and 31). IT10W indicates the

number of throttle settings stored in the thrust table. Its value must be at least 5 (that is, one must store thrust data at least at the five throttle settings -2., -1., 0., 1., 2. - see Reference 1, pg 225). IT10X indicates the number of Mach data points in the thrust table. The first TTAB10 card lists the throttle setting points in ascending order, followed by the Mach points in ascending order. The rest of the TTAB10 table contains the thrust data for one engine for fixed Mach (start with lowest Mach) and ascending throttle setting. The last data in the table is for the highest Mach setting and ascending throttle setting. The "displacement numbers" on the far right side of the TTAB10 cards is explained on pg 9.

2. LANDING GEAR MODIFICATION DATA

NSTRUT is the number of landing gears on the aircraft. It is synonymous with the variable K in Reference 1 (pg 74). The program is presently limited to a maximum value of 5 for NSTRUT. A minimum of 3 struts is necessary to support the aircraft on the runway. MASS is an array of the masses (i.e., m_k, see Reference 1, pgs 71 and 84) in slugs, of the main strut (i.e., strut, wheel frame, tires, etc.) of each landing gear. In each gear array there must be NSTRUT data points. The order of the data points is arbitrary but must be consistent in all gear arrays. If the data for the array exceeds that which can be put on one card, displacement numbers must be put on the following cards for that array. The arrays RX, RY, and RZ are the body coordinates R_{kx}, R_{ky}, R_{kz}, respectively, in feet, of the landing gear position vector $(\bar{R}_k)_o$ (Reference 1, pg 74 and Eq 114, pg 82) from the vehicle nominal mass center. It is these three gear position arrays that determine the appropriate order of the data in the other landing gear arrays. RX is positive in the forward nose direction. RY is positive out the right wing direction. RZ is positive down. THETAD is the array of angles θ_k (Reference 1, pgs 74 and 80) in degrees. ERDEG is the runway elevation angle E_{R} (Reference 1, pg 81) in degrees. RGR is the fixed distance R_{gR} (Reference 1, pg 81) in ft. NTIRES is an array of the number of tires n_k (Reference 1, pg 99) on each strut axle. RZERO is an array of

Column:

1	12	67
NSTRUT	5	
MASS	46.62149,132.0942,132.0942,132.0942	
MASS	132.0942	5
RX	62.34333,-1.42,-1.42,-19.75333,-19.75333	
RY	0.,-12.9375,12.9375.-12.9375,12.9375	
RZ	0.,0.,0.,0.,0.	
THETAD	0.,0.,0.,0.,0.	
ERDEG	0.	
RGR	1917.	
NTIRES	4.,6.,6.,6.,6.	
RZERO	2.011666,2.011666,2.011666,2.011666	
RZERO	2.011666	5
DF[illegible]M	.83333,.83333,.83333,.83333,.83333	
RLT	1.E+05	
IFD	1	
AI	125472.2,141992.9,141992.9,141992.9	
AI	141992.9	5
BI	1.32,1.293,[illegible].293,1.293,1.293	
FTAB02	2,0.,0.,1.E+05,0.	
FTAB03	14,[illegible],0.,.01,.2,.025,.3,.035,.4	
FTAB03	.065,.5,.09,.6,.15,.76,.2,.8,.24,.76	10
FTAB03	.325,.65,.5,.6,.7,.56,1[illegible]53,100.,.53	20
MOMENT	13.5,15.0,15.0,15.0,15.0	
MB	0.,0 0.,0.,0.	
RF	18.13666,18.55416,18.55416,18.[illegible]6	
RF	18.55416	5
VZ	[illegible]	
PZERO	304[illegible]0.4,41538.24,41538.24	
PZERO	41538.24,41538.24	4
VZERO	.5579861,1.162662,1.162662	
VZERO	1.162662,1.162662	4
A	.492222,.722222,.722222	
A	.722222,.722222	
P20	375840.,346154.4,346154.4	
P20	346154.4,346154.4	4
V20	.6060243,1.1179398,1.1179398	
V20	1.1179398.1.1179398	4
A2	.394444,.5118055,.5118055	
A2	.5118055,.5118055	4
IL	0	
S2T	.9062[illegible],.784166,.784166	
S2T	.784166,.784166	
ES2	.020833,.020833,.020833	
ES2	.020833,.020833	4
C2L	240.,240.,240.,240.,240.	

Column: 1	12	67
INDCO1	1	
NSMAIN	2	
CTABO1	0.,2.1,1.,2.,3.,4.,5.	
CTABO1	3024.,3024.,2160.,2160.,2160.,2160.	8
CTABO1	2160.,2160.,2160.,2160.	14
INDCO2	1	
CTABO2	0.,2.1,1.,2.,3.,4.,5.	
CTABO2	3024.,3024.,2160.,2160.,2160.,2160.	8
CTABO2	2160.,2160.,2160.,2160.	14
INDCO3	1	
NS2NDY	2	
CTABO3	0.,1.,1.,2.,3.,4.,5.	
CTABO3	72.,72.,72.,72.,72.,72.,72.,72.,72.,72.	8
INDCO4	1	
CTABO4	0.,1.,1.,2.,3.,4.,5.	
CTABO4	720.,720.,720.,720.,720.	8
CTABO4	720.,720.,720.,720.,720.	13
MASS2	3.108099,3.108099,3.108099	
MASS2	3.108099,3.108099	4
MUS	0.,0.,0.,0.,0.,	
ES	.020833,.020833,.020833	
ES	.020833,.020833	4
SB	1.83333,2.08333,2.08333	
SB	2.08333,2.08333	4
CASK	1.,0.,0.	

the outside tire radius rok (Reference 1, pg 110) in feet. DELTAM is an array of maximum tire deflections in feet. If actual tire deflections exceed these values, the tire is assumed to blowout and the program stops. RLT is the runway length in feet. IFD is an indicator which determines whether the tire force-deflection curves $f_k(\delta_k)$ (Reference 1, pg 99) are input as tables (i.e., table FTAB01) or in equation form. If IFD has the value one, the tire force deflection curves assume the equation form a_k (δ_k) b_k. The a_k and b_k constants are stored in the AI and BI arrays, respectively. The units of the data in the AI and BI arrays must be such that when δ_k is in feet, the function is in pounds. If IFD has the value zero, the tire force deflection curves are contained in a single two-dimensional table FTAB01. This table setup is similar to the thrust table TTAB10. The NSTRUT indicator (already input) is synonymous with the IT10X indicator of TTAB10 and indicates the number of force-deflection curves contained in FTAB01. The NDELTA indicator (not shown) indicates the number of δ_k points in each table f_k (δ_k). The NDELTA card is followed by the FTAB01 table which lists the NDELTA δ_k points (in ft) in ascending order, followed by the gear numbers (i.e., 1., 2., 3., etc., up to NSTRUT). The actual force data (lbs) for gear 1 then follows for ascending δ_k. This is followed by the force data for gear 2, then gear 3 etc., until there are NSTRUT tables contained in FTAB01. FTAB02 is the runway perturbation table $\varepsilon(X_{Rk})$ (Reference 1, pg 110). The independent variable is X_R in feet and the dependent variable is the runway perturbation ε in feet. FTAB03 is the tire-runway coefficient of friction table μ_k (Reference 1, pg 99). The independent variable is "P_{skdk}" (Reference 1, pg 218) whose range is 0. - 1.0. All tires are assumed to have the same μ_k properties. Note the difference in format for gear array input and gear table input (pgs. 9-10).

MOMENT is an array of the moments of inertial I_k (slug - ft^2) of a single tire-wheel combination (Reference 1, pgs 215-216) on each strut. MB is an array of the initial values given to the braking moment M_{Bk} (lb - ft). The values in the MB array are normally zero (Reference 1, pg 216). The RF array is the fully extended axle position r_{Fk} (Reference 1, pg 82) in feet. VZ is the velocity V_o (ft/sec) in Reference 1, pg 135.

Its value should be zero. The PZERO array is the preload pressure P_{ok} (lb/ft^2) of the upper air chamber (Reference 1, pg 86) for each gear. The VZERO arrary is the preload volume V_{ok} (ft^3) of the upper air chamber (Reference 1, pg 86) for each gear. The A array is the area A_k (ft^2) of the main piston (Reference 1, pg 86) for each strut. The P20, V20, A2 arrays are the preload pressure P_{ok2} (lb/ft^2), preload volume V_{ok2}(ft^3), and piston area A_{k2}(ft^2) (Reference 1, pg 86), respectively, for the secondary air chamber in each strut. An IL indicator value of 0 includes the secondary piston and air chamber in the gear-strut simulation. An IL indicator value of 1 removes the secondary piston and air chamber from the gear-strut simulation. The S2T array is the maximum allowed displacement S_{k2T} (ft) of the secondary piston (Reference 1, pg 95-97) for each strut. The ES2 array is the integration accuracy constraint E_{Sk2} (ft) for the secondary piston position of each strut. The C2L array is the linear drag coefficient C_{k2L}(lb-sec/ft) of the secondary piston (Reference 1, pg 88) for each strut. The CTAB01 table is the nonlinear damping coefficient of the main orifice C_k($lb\text{-}sec^2/ft^2$) for main strut compression (Reference 1, pg 93) for each strut. The CTAB02 table is the nonlinear damping coefficient of the main orifice C_k($lb\text{-}sec^2/ft^2$) for main strut extension for each strut. The CTAB03 table is the nonlinear damping coefficient of the secondary orifice C_{k2} ($lb\text{-}sec^2/ft^2$) for main strut compression (Reference 1, pg 93) for each strut. The CTAP04 table is the nonlinear damping coefficient of the secondary orifice C_{k2} ($lb\text{-}sec^2/ft^2$) for main strut extension for each strut. Each of the CTAB tables is two-dimensional and similar in input format to the FTAB01 table. The two independent variables are strut position and strut number. The CTAB tables each begin with the strut deflections followed by the strut numbers. The remainder of the data in each table is the value of the orifice coefficient for increasing strut deflection beginning with strut 1. NSMAIN is the number of independent strut positions stored for each main strut in tables CTAB01 and CTAB02. NS2NDY is the number of independent secondary piston positions stored for each strut in tables CTAB03 and CTAB04. If a table is to be used, its associated indicator (i.e., INDC01, etc.) is needed.

The MASS2 array is the mass M_{k2} (slugs) of each secondary piston (Reference 1, pg 92) in each strut. The array MUS is the coefficient of sliding friction μ_{sk} at the wing gear root (i.e., where the main strut is supported by the wing) for each strut (Reference 1, pg 88). The ES array is the integration accuracy constraint E_{Sk} (ft) for the main strut position (Reference 1, pg 95-97) of each strut. The SB array is the maximum allowed displacement S_{kb} (ft) of the main strut (Reference 1, pg 95-97) for each strut. The CASK array is an array of indicators denoting whether or not the corresponding gear is castered (i.e., its wheels allowed to align themselves with the axle velocity vector). A one value causes the gear to be castered. A zero value fixes the orientation of the axle relative to the body axes system.

3. AUTOPILOT DATA

Column: 1	12
INDAUT	1

A zero value for the INDAUT indicator deletes all autopilot calculations; a one value causes the autopilot calculations to be made.

a. Engine Data

Column: 1	12
IN	4
ZN	5.41,3.39,3.39,5.41
YN	61.8,39.7,-39.7,-61.8
N	1.975,-1.,-1.,1.975

The IN indicator is used to indicate the number of engines on the aircraft (Reference 1, pg 197). A minimum of one engine and a maximum of four engines can be simulated. The ZN and YN arrays are the Z, Y body coordinates (in ft) of each engine thrust vector origin. Because of the throttle autopilot, the data in the ZN and YN arrays must correspond to the engine physical arrangement in one direction along the wing. As discussed in Reference 1 (pg 227), the thrust vectors are assumed parallel to the

X longitudinal body axis; therefore, the engine X coordinates are not needed. The N array contains the initial throttle settings for each engine.

b. Drag Chute Data

Column: 1	12
ICS	0
CDCH	0.
SSH	0.
XCH	0.
YCH	0.
ZCH	0.

ICS the drag chute indicator signal (Reference 1, pgs 63 & 179), is usually initialized at a zero value. The variables CDCH, SSH, XCH, YCH and ZCH are the variables C_{DCH}, S_{SH} (ft^2), X_{CH} (ft), Y_{CH} (ft) and Z_{CH} (ft) respectively (Reference 1, pgs 61 & 62).

c. Phase Begin - Terminate Data

Column: 1	12
ITO	0
HF	100.
NF	0
XRF	100.
HRF	25.
DELTAH	3.
KP	0
TI	0.
NLRI	1
VS	10.
XS	10000.
TS	40.
HS	0.

The ITO indicator is the takeoff-landing indicator (Reference 1, pgs 180 & 182). A zero value is used for a landing problem and a one value for a takeoff problem. HF is the flare altitude h_F (ft) (Reference 1, pg 182). NF is the NF glide slope termination indicator (see Reference 1, pg 182). An NF value of zero allows the problem to go into the flare phase when the h_F altitude is reached. An N_F value of one terminates the problem at the glide slope end (i.e., h_F altitude). The variables

XRF and HRF are the initial values of the variables X_{RF} (ft) and h_{RF} (ft) (Reference 1, pgs 164 and 182). They are primarily used to start the problem in the "hold mode". DELTAH is the variable δ_h (ft) (Reference 1, pgs 180 & 182). Because of possible high flare guidance acceleration (i.e., A_{hR}) as flare termination is reached, δ_h should always have a nonzero positive value. KP is an indicator (Reference 1, pgs 180 & 182) used to start the problem in the landing roll phase. A KP value of zero allows the program to establish its own time of impact, T_I, and a KP value of one requires the impact time T_I (sec) to be read into the program as TI. NLRI is the NLR indicator (Reference 1, pgs 180 & 182). An NLRI value of one stops the problem on impact, and a value of zero allows the problem to continue after impact and terminate on one of the three runway stopping condition V_S (ft/sec), X_S (ft), T_S (sec) (Reference 1, pg 182) which are input as VS, XS, and TS, respectively. HS is the runway altitude h_s (ft), at which the takeoff roll is terminated (Reference 1, pgs 178 & 181).

d. Takeoff Condition Data

Column:	1	12
	VATO	0.
	ALPHTO	0.

VATO and ALPTHO are takeoff conditions V_{ATO} (ft/sec) and α_{TO} (deg) respectively (Reference 1, pgs 178 and 181).

e. Glide Slope Maneuver Data

Column:	1	12
	VD	220.
	DELVE	0.
	EPSGS	3.
	ALPHDS	-5.
	ALPHDL	14.
	HCG	20.56
	DELEPS	.05
	RFH	5.
	PGS	.04
	DELSIG	.1
	RFY	10.
	PHIC	1.0

VD is the desired inertial velocity down the glide slope V_d (ft/sec) (Reference 1, pg 152). DELVE is the velocity error ΔV_e (ft/sec) which should be input as zero. EPSGS is the glide slope elevation ε_{GS} (deg) (Reference 1, pg 148). ALPHDS and ALPHDL are the lower and upper limits α_{ds} (deg) and α_{dL} (deg), respectively (Reference 1, pg 160) for the glide slope desired angle of attack. HCG is the variable h_{CG} (ft) (Reference 1, pg 148). DELEPS is the allowed vertical glide slope angular error δ_ε (deg). RFH is the rate feedback constant RF_h (sec) and PGS is the phugoid control constant PG_s (deg/ft) (Reference 1, pgs 151 & 157). DELSIG is the allowed horizontal glide slope angular error $\delta\sigma$(deg), RFY is the rate feedback constant RF_y(sec), and PHIC is the roll control angle ϕ_c (deg) (Reference 1, pgs 149, 151, 153).

f. Flare Maneuver Data

Column: 1	12
XTD	100.
HTD	25.
VXTD	200.
VHTD	-1.
IIR	0
LD	5000.
DA	.02
TL	5000.
TU	126000.

XTD is the variable x_{TD} (ft) which locates the runway beginning with respect to the glide slope origin (Reference 1, pg 167). HTD, VXTD and VHTD are the initial desired touchdown conditions h_{TD} (ft), V_{xTD} (ft/sec), and V_{hTD} (ft/sec), respectively. IIR is the indicator IR (Reference 1, pg 173) and should always have a zero initial value. LD is the expected runway landing distance L_D (ft). DA is the accuracy (in deg) of the α_d search done to solve the nonlinear simultaneous equations (Reference 1, pgs 171 & 176, Equations 299 and 300) for the flare α_d, T_d commands. TL (lbs) and TU (lbs) are the lower and upper bounds, respectively, on the desired thrust, T_d, in the flare.

g. Hold Maneuver Data

Column: 1		12
ALPDES		6.5896
TTD		47073.
KF	INT	1,1,1,1
PM		11.

If the problem is started in the hold mode, α_d (deg) and T_d (lbs) must be input to the problem as the variables ALPDES and TTD, respectively. KE is the "kill engine" indicator array (Reference 1, pgs 172, 198, & 203). This allows the option to pull the throttles back to forward idle (if the engines are not in a fixed mode) in the hold mode. A one value in the array exercises the kill power option for that particular engine, and a zero value leaves that particular engine at the previous fixed thrust level. PM is the tail down constraint angle P_m (deg) (Reference 1, pgs 172 & 177).

h. Landing Roll Maneuver Data

Column: 1	12
TSP	1.
TRV	3.
TCH	0.
TBK	2.
ISS	0.
ILR	0
IBS	0

TSP, TRV, TCH and TBK are the variables t_{sp} (sec), t_{rv} (sec), t_{ch} (sec), and t_{bk} (sec), respectively (Reference 1, pg 179). ISS, ILR, and IBS are the initial values of the indicators ISS, ILR, and IBS, respectively (Reference 1, pg 179). These indicators are normally input as zero (note ISS is the only indicator that is floating point).

i. Engine Failure Stage Data

Column: 1	8	12
IC	INT	1,1,1,1
XRF1		0.
IT1	INT	1,1,1,1
XRF2		0.
IT2	INT	1,1,1,1
H1		0.
IH1	INT	1,1,1,1
H2		0.
IH2	INT	1,1,1,1
HR1		0.
IHR1	INT	1,1,1,1
HR2		0.
IHR2	INT	1,1,1,1
TR1		0.
ITR1	INT	1,1,1,1
TR2		0.
ITR2	INT	1,1,1,1

The IC array contains the initial values for the IC (I) array (Reference 1, pgs 183 & 184). A one value in the array indicates the engine is working, and a zero value indicates engine failure. Reference 1, pg 184 and the following indicates the other variables:

XRF1 - X_{RF1}(ft)

IT1 - IT1(I)

XRF2 - X_{RF2}(ft)

IT2 - IT2(I)

H1 - h_1(ft)

IH1 - IH1(I)

H2 - h_2(ft)

IH2 - IH2(I)

HR1 - h_{R1}(ft)

IHR1 - IHR1(I)

HR2 - h_{R2}(ft)

IHR2 - IHR2(I)

TR1 - t_{r1}(sec)

ITR1 - ITR1(I)

TR2 - t_{r2}(sec)

ITR2 - ITR2(I)

j. Brake Condition Stage Data

Column: 1	8	12
IB	INT	0,1,1,1,1
TBK1		100.
IBK1	INT	0,1,1,1,1
TBK2		100.
IBK2	INT	0,1,1,1,1

The IB array contains the initial values of the brake condition array I_{Bi} (Reference 1, pgs 183 & 185). The variables TBK1 and TBK2 are t_{bk1} (sec) and t_{bk2} (sec), respectively. The arrays IBK1 and IBK2 are the arrays I_{Bk1}(I) and I_{Bk2}(I), respectively.

k. Pitch Autopilot Data

Column: 1	12	1	12
ALPDL	1.	DFLQC2	0.
RFALPH	.5	TST	5.0
DELALA	.01	DELQF	0.
PSH	-20.	DELFD1	1.
PSH2	-20.	DELQTO	0.
RFALP2	.5	DELQL	-15.
DFLQC	0.	DELQU	25.

ALPDL (deg/sec) is the maximum α_d allowed in the pitch autopilot (Reference 1, pg 191) RFALPH is the rate feedback constant $R_{F\alpha}$ (sec) (Reference 1, pgs 188 & 189). DELALA is the allowed angular error $\Delta\alpha_a$ (deg). PSH is the overcontrol sensitivity PS_H (deg/deg) (note sign). RFALP2 and PSH2 are the flare, hold, landing roll & takeoff values for RF_α and PS_H, respectively (Reference 1, pg 189). DELQC and DELQC2 are the "bang-bang" control magnitude δ_{qc} (deg) (Reference 1, pg 189 & 191) for glide slope and flare (etc), respectively. TST is the nose-over time t_{st} (sec) (Reference 1, pgs 188 & 189). DELFD1 is the angular

rate δ_F (deg/sec) and DELQF is the final nose-over elevator deflection δ_{qF} (deg) (Reference 1, pgs 188 & 189). DELQTO is the takeoff elevator initial deflection δ_{qTO} (deg). DELQL and DELQU are the lower and upper elevator deflection limits δ_{qL} (deg) and δ_{qu} (deg), respectively (Reference 1, pgs 188 & 190).

l. Yaw Autopilot Data

Column: 1	12
RFB	.5
DELBA	.05
PSR	10.
RFPSI	.5
DPSIA	.05
PSPSI	-10.
DELRL	-35.
DELRU	35.

RFB is the rate feedback constant $R_{F\beta}$(sec) (Reference 1, pgs 192 & 193) DELBA is the allowed angular error $\Delta\beta_a$(deg). PSR is the overcontrol constant PS_R (deg/deg). RFPSI is the rate feedback constant $R_{F\psi}$ (sec) (Reference 1, pgs 192 & 193). DPSIA is the allowed angular error $\Delta\psi_a$(deg). PSPSI is the overcontrol constant (note sign) PS_ψ (deg/deg). DELRL and DELRU are the lower δ_{rL} (deg) and upper δ_{ru} (deg) rudder deflection limits respectively.

m. Roll Autopilot Data

Column: 1	12
RFPHI	.5
DPHIA	.05
PSA	-15.
DELPL	-60.
DELPU	60.

RFPHI is the rate feedback constant $R_{F\phi}$ (sec) (see Reference 1, pgs 194 & 195). DPHIA is the allowed angular error $\Delta\phi_a$(deg). PSA is the control constant PS_A (deg/deg). DELPL and DELPU are the lower δ_{PL} (deg) and upper δ_{Pu} (deg) aileron deflection limits respectively.

n. Throttle Autopilot Data

Column: 1	8	12	67
TF	INT	0,1,1,0	
NDF		0.,-1.,-1.,0.	
IR	INT	1,1,1,1	
NB		1.05,1.05,1.05,1.05	
NLR		-2.,-2.,-2.,-2.	
NTO		2.,2.,2.,2.	
K2		.5	
K3		.5,.5,.5,.3333,.3333	
K4		.5,.5,.5,.5,.3333,.3333,.3333,.3333	
K4		.25,.25,.25	9

The TF array is the throttle fix indicator array TF (I) (Reference 1, pg 204). The NDF array is the fixed throttle setting array $N_{dF}(I)$. The IR array is the engine reverse capability indicator array IR (I) (Reference 1, pgs 198, 204, 208, 210, 212-215). The NB array is the engine throttle constraint array for reverse N_B (I). The NLR array is the reverse throttle setting array for landing, N_{LR} (I). The NTO array is the takeoff throttle setting array N_{TO} (I). K2 is the engine load factor $k_{(2)121}$ (Reference 1, pgs 203 & 204). The K3 array contains the engine load factor constants $k_{(3)131}$, $k_{(3)232}$, $k_{(3)121}$, $k_{(3)1231}$, $k_{(3)1232}$, in that order. The K4 array contains the engine load factor constants $k_{(4)141}$, $k_{(4)232}$, $k_{(4)343}$, $k_{(4)242}$, $k_{(4)2342}$, $k_{(4)2343}$, $k_{(4)1341}$, $k_{(4)1343}$, $k_{(4)12341}$, $k_{(4)12342}$, $k_{(4)12343}$, in that order.

o. Brake Autopilot Data

Column: 1	12
MBC	0.,0.,0.,0.,0.
PD	.01
DELTAW	.001
OMECDI	20.
MBL	0.,0.,0.,0.,0.
MBU	3.E5,3.E5,3.E5,3.E5,3.E5

The MBC array is the constant braking array M_{BCI} (lb-ft) (Reference 1, pgs 217 & 218. PD is the desired percent skid P_D. DELTAW is the allowed fraction wheel speed error, $\Delta\omega$. ϕMECDI is the control tire angular acceleration $\dot{\omega}_c$ $^{rad}/_{sec^2}$. The arrays MBL and MBU are lower nl_{BLi} (lb-ft) and upper M_{Bui} (lb-ft) braking moment limit arrays (Reference 1, pgs 219 & 222).

p. Control Response Data

Column: 1	12
DELHS	25.
DELRRD	35.
DELA	60.
NED1	.125

DELHS, DELRRD, DELA, and NED1 are the control variable rates $\dot{\delta}_{HS}\left(^{deg}/_{sec}\right)$, $\dot{\delta}_{RD}\left(^{deg}/_{sec}\right)$, $\dot{\delta}_{A}\left(^{deg}/_{sec}\right)$, and $\dot{N}_{E}\left(^{1}/_{sec}\right)$, respectively (Reference 1, pg 224).

q. Initialization

Column: 1	12	1	12
IAP	1	MANLOG	1
HR	0.	PITCHP	1
DELQN	0.	YAWAUP	1
DELQDE	.07227	ROLLAP	1
DELQD	.07227	THROAP	1
DELPD	0.	BRAKAP	1
DELRD	0.	CONTRP	1
AUXICP	1	INDICP	1

IAP, HR, DELQN, DELQDE, DELQD, DELPD, and DELRD are initial input values of IAP, h_R(ft), δ_{qn}(deg), δ_{qd}(deg), δ_q(deg), δ_p(deg), δr(deg), respectively (Reference 1, list of symbols).

r. Autopilot Output Indicators

There are nine categories of autopilot output: auxiliary computations, maneuver logic, pitch autopilot, yaw autopilot, roll autopilot, throttle autopilot, brake autopilot, control response, and status indicators. The following nine indicators: AUXICP, MANLOG, PITCHP, YAWAUP, ROLLAP, THROAP, BRAKAP, CONTRP, INDICP are associated respectively to the nine categories of autopilot output. The indicators initially have a zero value which eliminates all autopilot output. If the indicator on input is given a one value, the output will be printed. See Section III, paragraph 2, for details. If used, these indicators follow the initialization card inputs just discussed.

s. Plot Tape Data

A magnetic tape may be used to output selected rigid body data and selected landing gear data. A request or label card is needed after the JφB card to mount a tape. The following data is also required in the first stage of the data decks.

Card Column:	1	12
	IPLT	1
	ISDF	1
	ISTPL1	1
	ISTPL2	1
	ISTPL3	1
	ISTPL4	1
	ISTPL5	1

IPLT = 1 denotes that data will be saved on a tape for plotting. ISDF = 1 denotes rigid body data will be saved on tape. ISTPL1 = 1, ISTPL2 = 1, ISTPL3 = 1, ... etc., denote that data for landing gears numbers 1, 2, 3, ... etc., will be saved on tape. ISDF = 1 saves L_m, M_m, N_m, q, θ_p, ψ_p, ϕ_p, F_{zm}, a_z, $\dot{z}_g$, h_g, X_g, Y_g, a_x, $\dot{x}_g$ at each printed time. ISTPLk = 1 saves F_{Tk}, S_{Fk}, δ_k, P_k, P_{2k}, $\ddot{S}_k$, $\dot{S}_k$, S_k, $\ddot{S}_{2k}$, $\dot{S}_{2k}$, S_{2k}, M_{Ak}, $\dot{\omega}_{Tk}$, ω_{Tk} at each printed time. A separate computer program is needed to further reduce this data for Calcomp plots. Use of this separate program is explained in the last volume of this report.

4. STAGING DATA

Pages 32-33 explain the basic staging options available. One additional staging option was added which will be explained later. The general staging logic is so built that almost any kind of staging can be done. As shall be seen, the specific staging done in large part controls the time efficiency of the program and parts of the staging is a must to even get the program to run.

a. Staging Gears Into Program

The added calculations to account for the landing gears is voluminous and time consuming. Even though the gear computations can be made and

correct answers obtained during vehicle free flight (i.e. glide slope and flare), these calculations are unnecessary. The following staging is therefore done first:

Column:	1	8	12
	INDLG		0
	ISTAGE		0
	DECRES	BCD	1 HR
	STESTD		25.
		TRA	
	INDLG		-1

The zero INDLG indication prevents the gear calculations from being made. As the aircraft nears the ground and impact approaches (this is sensed by a decreasing test on the runway altitude, h_R (ft), the gear calculations are staged into the program. In this particular test, the gear calculations were staged in when $h_R \leq 25$ ft. The change in data required is a value of -1 for the INDLG indicator. Note that the particular value of h_R for this stage must be sufficiently greater than h_{cg} to insure that impact does not occur before the stage is made. When the gears are staged in, the initial values of main strut position, S_k, main strut velocity, $\dot{S}_k$, secondary piston position, S_{k2}, secondary piston velocity, $\dot{S}_{k2}$, and tire angular rate, ω_{Tk}, are all automatically zero. If the problem begins on the runway, as in the takeoff roll, the initial values in the arrays S_k, $\dot{S}_k$, S_{k2}, $\dot{S}_{k2}$ and ω_{Tk} must be read in. This is done through the following variables which are placed immediately after the INDLG card:

S1 ~ S_1 (ft)

S2 ~ S_2 (ft)

S3 ~ S_3 (ft)

S4 ~ S_4 (ft)

S5 ~ S_5 (ft)

SD11 ~ $\dot{S}_1$ (ft/sec)

SD12 ~ $\dot{S}_2$ (ft/sec)

SD13 ~ $\dot{S}_3$ (ft/sec)

SD14 ~ $\dot{S}_4$ (ft/sec)

SD15 ~ $\dot{S}_5$ (ft/sec)

S21 ~ S_{12} (ft)

S22 ~ S_{22} (ft)

S23 ~ S_{32} (ft)

S24 ~ S_{42} (ft)

S25 ~ S_{52} (ft)

S2D11 ~ $\dot{S}_{12}$ (ft/sec)

S2D12 ~ $\dot{S}_{22}$ (ft/sec)

S2D13 ~ $\dot{S}_{32}$ (ft/sec)

S2D14 ~ $\dot{S}_{42}$ (ft/sec)

S2D15 ~ $\dot{S}_{52}$ (ft/sec)

OMT1 ~ ω_{T1} (rad/sec)

OMT2 ~ ω_{T2} (rad/sec)

OMT3 ~ ω_{T3} (rad/sec)

OMT4 ~ ω_{T4} (rad/sec)

OMT5 ~ ω_{T5} (rad/sec)

This gear stage is always the first stage and is considered a must for a time efficient program.

b. Smooth Impact Stage

The second stage (also a must) can be looked up as an impending impact stage.

Column: 1	8	12
AINCRS	BCD	4DDELT1DDELT2DDELT4DDELT5
STEST		-1.,-1.,-1.,-1.
	TRA	
PRINT		.01
DELTS		.01
AMAXER		.001
PRTMIN		0.

The heights of each wheel bottom surface (see δ_k in Appendix II) above the runway (note this is a negative value) are given the names DDELT1 --- DDELT5. As these numbers approach zero, impact occurs. On this particular test, the stage was performed when bottom surface of wheels 1, 2, 4, or 5 was less than one foot off the runway. At this point the required data change is a small VSRK maximum interval, that is AMAXER. This insures a smooth impact. Note that when AMAXER is changed, the integration data constraint PRTMIN $\leq$ AMAXER $\leq$ DELTS $\leq$ PRINT must still hold. Note also that the h_R value in the initial stage must be large enough to insure that the wheel bottom surfaces are at least one foot off the runway (in this case) when the gears are stage in. The reason for this is that the variables DDELT1 --- DDELT5 don't even exist until the gear calculations are staged in. This is a good time to assert an important point about the staging logic: that is, the stages will only occur in the order they appear in the data deck. Therefore, one must make sure that the stages are in the proper sequence and staged on the variables appropriate to sense that sequence.

c. Efficient AMAXER Stage

The small AMAXER of the previous stage was used solely to insure a smooth impact. To leave AMAXER at this small value would not be very

time efficient, thereby severely limiting the capability of the VSRK integration interval. As soon as impact occurs occurs and the VSRK technique has had an opportunity to pick an appropriate integration interval, AMAXER should be staged back to a reasonable value. This is done as follows:

```
Column:  1      8    12
________________________
         AINCRS  BCD  4DELTA1DELTA2DELTA4DELTA5
         STEST        .1,.1,.1,.1
                 TRA
         PRINT        .08
         AMAXER       .04
         DELTS        .04
```

The tire deflections DELTA1 --- DELTA5 are used as the staging variable. The particular tire deflection in this stage was 0.1 foot.

d. Spoiler Aero Stage

If the aircraft is landing, the next stage is spoiler actuation (if spoilers exist on the aircraft). The staging variable is the spoiler actuation signal ISS. The required data change is the appropriate

```
Column:  1      8    12
________________________
         AINCRS  BCD  1ISS
         STEST        1.
                 TRA
         ATAB10       .030,.030
         ATAB11       .1162,.1162
         ATAB12       0.,0.
         ATAB51       .3439,.3439
         ATAB52       -.0327,-.0327
         ATAB53       0.,0.
         ATAB80       .267,.267
```

aerodynamic coefficient tables with spoilers activated. Since the spoiler signal is based on a specific time after timpact, t_{sp}, one has to make sure that the staging tire deflection of the previous stage is not too large so as not to occur before t_{sp}. If t_{sp} is very small (i.e., like 0. etc.), then the spoiler stage may have to be placed before the efficient AMAXER stage.

e. Bounce Stage

A combination of high sink rate, no spoilers (or late spoiler actuation), stiff landing gear strut, and a light aircraft can create a situation where the entire aircraft may bounce completely off the runway. To sense this condition, the staging logic had to be modified. By giving the ISTAGE indicator a value of one (it was initially zero), all four variables (not just one) in the stage testing logic must meet the increasing or decreasing constraints before the stage is performed. The bounce stage is therefore as follows:

Column: 1	8	12
ISTAGE		1
DECRES	BCD	4DELTA1DELTA2DELTA4DELTA5
STESTD		0.,0.,0.,0.
	TRA	
AMAXER		.001
DELTS		.01
PRINT		.01
ISTAGE		0
AINCRS	BCD	4DDELT1DDELT2DDELT4DDELT5
STFST		.1,.1,.1,.1
	TRA	
AMAXER		.05
DELTS		.1
PRINT		.1

First a decreasing test is done to check if the aircraft bounced; that is, see if the tire deflections DELTA1 --- DELTA5 have reached zero. AMAXER is then given a small value, as before, to insure a second smooth impact. ISTAGE is given a zero value again and a second stage similar to the efficient AMAXER stage follows. This staging is sufficient to get the aircraft through one complete bounce. As many bounce stages as one feels is needed can be used.

f. Data Deck End

The last stage is ended with the following cards:

Column: 1	8	12
INDSTF		1
	TRA	
END of JOB card		

This concludes the data deck setup.

SECTION VI

OUTPUT

The time intervals for computer output are PRTMIN and PRINT (see discussion on pages 47-48). As previously discussed, the PRTMIN option should not be used unless one is really interested in the high frequency response of the landing gears. The long term response of the gears and main airframe can be approximated by a PRINT value of about 0.1 or 0.2 seconds. The selection of a PRINT value should, however, be tempered by the frequency of the specific output to be examined. The reason for this print interval caution is that there can be as much as 50 lines of output each time a PRTMIN or PRINT option is exercised. For the computer system available to AFFDL, experience has shown the TOLA problem to be output bound in such a case. Therefore, use of a PRINT interval smaller than that which is needed will result in a computation time longer than needed.

1. TRAJECTORY PRINTING METHOD

The printing of a trajectory may be divided into four categories.

a. Initial Printing - The printing of specific values at the first stage and at each subsequent major stage.

b. Code Printing - The printing of codes which will identify the variables which are to be obtained in the coming time history print.

c. Time History Printing - The printing of values specified at the requested points of the trajectory.

d. Diagnostic Error Printing - The printing of errors detected by the program.

All input data involved for a case is printed on the output page preceding the computation of the first stage printout. Also, data read in at stage times will be printed out between the stages of the trajectory output.

Initial print is designed to print certain values which will be constant during the trajectory and serves as a reminder of what values have been used for these constants.

Code printing is performed once per major stage to identify the time history.

The time history print is designed to print in a minimum space. That is, if a certain variable is not desired as output, it is not printed and other desired variables are moved in the print format accordingly.

The entire printing is controlled to print on a page 11 x 14 inches and will print a maximum of 54 lines per page. Page ejection and line control are provided by the subroutines DEF and LINES.

There are three basic kinds of TOLA output:
main airframe, autopilot, and landing gears.

2. MAIN AIRFRAME OUTPUT

There are two places during the run which may print a set of symbols, initial print and time history print. This section will present (1) the computer symbol, (2) its associated engineering symbol (if any), (3) the unit of measure, and (4) remarks.

(1) Initial Print

None

(2) Time History Print

Symbol	Quantity	Units	Remarks
ALPHD	α	deg	Angle of attack
ALPHD1	α	deg/sec	Rate of change of angle of attack
AMACH	M_N		Mach Number
AX77F	a_x	ft/sec^2	Body component of inertial acceleration
AXP7F	A_{xp}	ft/sec^2	Platform acceleration
AY77F	a_y	ft/sec^2	Body component of inertial acceleration
AYP7F	A_{yp}	ft/sec^2	Platform acceleration
AZ77F	a_z	ft/sec^2	Body component of inertial acceleration
AZP7F	A_{zp}	ft/sec^2	Platform acceleration
BETAD	β	eg	Angle of sideslip
BETAD1	$\dot{\beta}$	deg/sec	Rate of change of angle of sideslip
DYNPP	q^*	lbs/ft^2	Dynamic pressure
FCX	F_{cx}	lbs	Body component of drag chute force
FCY	F_{cy}	lbs	Body component of drag chute force
FCZ	F_{cz}	lbs	Body component of drag chute force
FDC	F_{DC}	lbs	Total drag chute force
GAM7D	γ	deg	Elevation flight path angle
GAM7R1	$\dot{\gamma}$	rad/sec	Rate of change of elevation flight path angle
HGC7F	h	ft	Geodetic altitude
PHIPD	ϕ_p	deg	Angle between body axis and platform axis

Symbol	Quantity	Units	Remarks
P177R	p	rad/sec	Inertial angular rate of body x axis
PSIPD	ψ_p	deg	Angle between body axis and platform axis
Q177R	q	rad/sec	Inertial angular rate of body, y axis
RG77N	R_g	naut. miles	Approx. range from launch point
R177R	r	rad/sec	Inertial angular rate of body, z axis
SIG7D	σ	deg	Horizontal flight path angle
SIG7R1	$\dot{\sigma}$	rad/sec	Rate of change of horizontal flight path angle
THTPD	θ_p	deg	Angle between body axis and platform axis
THTRD	θ_r	deg	Pitch angle between rotating machinery axis and body axis
TIME	t	sec	Flight Time
TIMES	ts	sec	Stage Time
U777F	u	ft/sec	Inertial velocity component along body x axis
V777F	v	ft/sec	Inertial velocity component along body y axis
VA77F	V_A	ft/sec	Airspeed
VG77F	V_g	ft/sec	Ground referenced speed
W777F	w	ft/sec	Initial velocity component along body z axis
WTR7P	W_t	lbs	Weight of body
XG77F	X_g	ft	Downrange
XG77F1	$\dot{X}_g$	ft/sec	Rate of change of downrange
YG77F	Y_g	ft	Crossrange
YG77F1	$\dot{Y}_g$	ft/sec	Rate of change of crossrange
ZG77F1	$\dot{Z}_g$	ft/sec	Rate of change of altitude

Aerodynamic Forces and Moments - SACS

(1) Initial Print

None

(2) Time History Print

Symbol	Quantity	Units	Remarks
CA	C_A	-	Axial force coefficient
CAVAH	C_{A_0}	-	C_a at $\alpha = \beta = 0°$
CM	C_m		Pitching moment coefficient
CN	C_N	-	Normal force coefficient
CRM	C_l	-	Rolling moment coefficient
CY	C_y	-	Side force coefficient (body axis)
CYM	C_n	-	Yawing moment coefficient

Engine Thrust and Fuel Flow - TFFS

(1) Initial Print

None

(2) Time History Print

Symbol	Quantity	Units	Remarks
Mt	M_T	ft-lbs	Net engine pitch moment
NT	N_T	ft-lbs	Net engine yaw moment
T(I)	T_i	lbs	Actual thrust array

Vehicle Physical Characteristics - VPCS

(1) Initial Print

Symbol	Quantity	Units	Remarks
AREFF	S	ft^2	Reference area
D1RFF	d_1	ft	Reference length for longitudinal aerodynamics
D2RFF	d_2	ft	Reference length for lateral and directional aerodynamics
XCGRF	$X_{C.G.REF}$	ft	Longitudinal position of center of gravity

(2) Time History Print

Symbol	Quantity	Units	Remarks
AMASS	m	slugs	Vehicle mass

3. AUTOPILOT OUTPUT

The autopilot printout is divided into nine categories: auxiliary computations, maneuver logic, pitch autopilot, yaw autopilot, roll autopilot, throttle autopilot, brake autopilot, control response, and status indicators. Depending on the values of the autopilot output indicators, (see Section II Para. 3r pg. 24) any combination of the nine categories can appear in the autopilot output.

a. Auxiliary Computations Output (AUXICP=1)

The output variables here are X_R (ft), Y_R (ft), Z_R (ft), $\dot{X}_R$ (ft/sec), $\dot{Y}_R$ (ft/sec), $\dot{Z}_R$ (ft/sec), $\dot{\psi}_P$ (deg/sec), and $\dot{\phi}_P$ (deg/sec) (see Ref. 1, pg 226) whose column designations are XR, YR, ZR, XRDI, YRDI, ZRDI, PSIPDI, and PHIPDI respectively.

b. Maneuver Logic Output (MANLφG=1)

The output variables here depend on whether the problem phase is glide slope, flare, landing roll, or takeoff roll.

(1) Glide Slope Output (IAP=1)

The variables output here are V_e (ft/sec), V_{ad}(ft/sec), γ_R(deg), Q_R(lb/ft^2), C_{LR}, α_d(deg), L_R(lbs), D_R(lbs), T_d(lbs), h_{GS}(ft), R_R(ft), h_{ea}(ft), h_e(ft), h_{eT}(ft), h_{pa}(ft), h_{pt}(ft), and ϕ_d(deg) (see Ref. 1, pgs 160 & 161) whose column designations are VE, VAD, GAMPR, QR, CLR, ALPDES, LR, DR, TD, HGS, RR, HEA, HE, HET, HPT, and PHIDES respectively.

(2) Flare Output (IAP=2,3)

The variables output here are t_x(sec), t_h(sec), x_{TD}(ft), h_{TD}(ft), V_{xTD}(ft/sec), V_{hTD}(ft/sec), X_{RF}(ft), $\dot{X}_{RF}$(ft/sec), h_{RF}(ft), $\dot{h}_{RF}$(ft/sec), A_{xR}(ft/sec^2), A_{hR}(ft/sec^2), α_d(deg), T_d(lbs), and ϕ_d(deg) & D_m(ft) (Ref 1, pg 173-176) whose column designations are TX, TH, XTD, HTD, VXTD, VHTD, XRF, XRFDI, HRF, HRFDI, AXR, AHR, ALPDES, TD, PHIDES, and DM, respectively. As the flare enters the hold mode, only α_d, ϕ_d and T_d are output.

(3) Landing Roll Output (IAP=4)

The variables output here are ISS, ILR, ICS, IBS, T_I(sec), and t_r(sec) (Reference 1, pg 195) whose column designations are ISS, ILR, ICS, IBS, TI, and TR, respectively.

(4) Takeoff Roll (IAP=5, 6)

There is no specific output for the maneuver logic of the takeoff roll phase.

c. Pitch Autopilot Output (PITCHP=1)

The variables output here are δ_{qn}(deg), α_e(deg), $\dot{\alpha}\left(\frac{deg}{sec}\right)$, $\dot{\alpha}_d\left(\frac{deg}{sec}\right)$, α_{eT}(deg), and δ_{qd}(deg) (Reference 1, pg 189) whose column designations are DELQN, ALPHAE, ALPHdI, ALPDDI ALPHET, and DELQDE, respectively.

d. Yaw Autopilot Output (YAWAUP=1)

The variables output here are δ_{rn}(deg), β_e(deg), $\dot{\beta}\left(\frac{deg}{sec}\right)$, β_{ei}(deg), δ_{rd}(deg), ψ_e(deg), and ψ_{eT}(deg) (Reference 1, pg 193) whose column designations are DELQR, BETAD, BETADI, BETAET, DELRDE, PSIE, and PSIET, respectively.

e. Roll Autopilot Output (RφLLAP=1)

The variables output here are ϕ_e(deg), ϕ_{eT}(deg), and δ_{pd}(deg) (Reference 1, pg 195) whose column designations are PHIE, PHIET, and DELPDE, respectively.

f. Throttle Autopilot Output (THRφAP=1)

The variables output here are the two arrays N_d(I) and T_d(I) (Reference 1, pgs 196-216) whose column designations are ND (IN) and TD (IN), respectively.

g. Brake Autopilot Output (BRAKAP=1)

The basic output variable here is the braking moment array M_{Bi}(lb-ft). When the braking signal (IBS = 1) is given in the landing roll, arrays $\omega_{TRi}\left(\frac{rad}{sec}\right)$, $\dot{\omega}_{TRi}\left(\frac{rad}{sec^2}\right)$, and $\omega_{TEi}\left(\frac{rad}{sec}\right)$ (Reference 1, pg 221) are also output. The array output names are MB(I), OMEGATR(I), OMEGATRD1(I), and OMEGATE(I), respectively.

h. Control Response (CφNTRP=1)

The variables output here are $\dot{\delta}_q\left(\frac{deg}{sec}\right)$, $\dot{\delta}_r\left(\frac{deg}{sec}\right)$, $\dot{\delta}_p\left(\frac{deg}{sec}\right)$, δ_q(deg), δ_r(deg), δ_p(deg) and the arrays $\dot{N}_{(i)}$ and $N_{(i)}$ (Reference 1, pg 224) whose column designations are DELQD1, DELRD1, DELPD1, DELQD, DELRD, DELPD, ND1, and N, respectively.

i. Status Indicator Output (INDICP=1)

The problem phase indicator IAP and the indicator arrays IC(I) and I_{Bi} are output here under the names IAP, IC(I) and IB(I), respectively.

4. LANDING GEAR OUTPUT

The gears must be staged in (see pg 69) for gear output to occur. The kind and amount of gear output depends on the indicator INDLG.

a. INDLG = -1

This value of the indicator is used to stage in the gears and do all calculations required to obtain strut positions, velocities, and wheel speeds. Gear output under this condition is as follows:

Variable	Output Name
δ_K(ft)	DELTA
P_K(lb/ft^2)	P
P_{K2}(lb/ft^2)	P2
F_{TK}(lbs)	FT

Variable	Output Name	Variable	Output Name
$S_{RK}(^{ft}/sec^2)$	SR	$F_{TRA}(lbs)$	FTRA
$S_{FK}(lbs)$	SF	$F_{TRB}(lbs)$	FTRB
$Q_K(^{ft}/sec^2)$	AA	$F_{TRC}(lbs)$	FTRC
$F_{CK2}(lbs)$	FC2	$M_{TX}(lb\text{-}ft)$	MTX
μ_K	MUVP	$M_{TY}(lb\text{-}ft)$	MTY
$V_{GPTK}(^{ft}/sec)$	VGPT	$M_{TZ}(lb\text{-}ft)$	MTZ
$F_{TRXK}(lbs)$	FTRX	$F_{XM}(lbs)$	FXM
$F_{TRYK}(lbs)$	FTRY	$F_{YM}(lbs)$	FYM
$F_{TR3K}(lbs)$	FTRZ	$F_{3M}(lbs)$	FZM
$M_{AK}(lb\text{-}ft)$	MA	$L_M(lb\text{-}ft)$	LM
$M_{BK}(lb\text{-}ft)$	MB	$M_M(lb\text{-}ft)$	MM
δ_K (ft)	DDELTA	$N_M(lb\text{-}ft)$	NM
$\ddot{S}_K(^{ft}/sec^2)$	SD2		
$\dot{S}_K(^{ft}/sec)$	SD1		
$S_K(ft)$	S		
$\ddot{S}_{K2}(^{ft}/sec^2)$	S2D2		
$\dot{S}_{K2}(^{ft}/sec)$	S2D1		
$S_{K2}(ft)$	S2		
$\dot{\omega}_{TK}(^{rad}/sec^2)$	OMETD1		
$\omega_{TK}(^{rad}/sec)$	OMET		

All variables are explicitly defined in Reference 1 except $+\delta_k$ and S_{Fk} $+\delta_k$ is only the positive value of δ_k (Reference 1, Eq. 199). If δ_k is negative, $+\delta_k$ is given a zero value; $+\delta_k$ represents the actual tire deflection. S_{Fk} is the sum of forces resisting main strut movement, that is

$$S_{FK} = -P_{AK} + F_{CK2} - C_{K2}\dot{S}_{K2}\left|\dot{S}_{K2}\right| - C_{K2L}\,\dot{S}_{K2} +$$

$$- F_{fK}\frac{\dot{S}_K}{\left|\dot{S}_K\right|} \quad \text{(see Eq 139 Ref. 1).}$$

b. INDLG = 2

This value of the indicator is used in the Stiff Strut Stage. Since the strut positions, velocities, and wheel speeds are fixed in this stage, only the following output is made: $+\delta_K$, F_{TK}, μ_K, F_{TRXK}, F_{TRYK}, F_{TR3K}, δ_K, S_K, F_{TRA}, F_{TRB}, F_{TRC}, M_{TX}, M_{TY}, M_{TZ}, F_{XM}, F_{YM}, F_{3M}, L_M, M_M and N_M.

The output column names remain unchanged from the previous case.

Several closing comments are appropriate as regards the output. As was mentioned on pg 48, the autopilot calculations are only updated every time interval DELTS. If a PRTMIN is reached, an autopilot output may or may not occur depending on how PRTMIN falls within the DELTS interval. Autopilot output will always appear on a PRINT condition. However, to make the autopilot output pertain to the specific data in the SDF-2 output, the PRINT interval must be the same as DELTS or an integer multiple of DELTS.

SECTION VII

PROGRAM USE

The amount of specific data needed in the data deck depends on the problem phase to be studied. TOLA was designed for conventional, powered aircraft and therefore has certain limitations when applied to unconventional vehicles. These limitations are also closely associated with the problem phase to be studied.

1. GLIDE SLOPE

There are two basic glide slope assumptions: The glide slope elevation angle, ε_{Gs} is small; the vehicle is powered. Both are valid assumptions for conventional, powered aircraft. As such, the powered vehicle can maintain a specific glide slope position and velocity down the glide slope subject to different wind conditions and aerodynamic changes due to ground effect. An unpowered vehicle, however, does not have this glide slope control flexibility. For a given longitudinal trim, the glide slope angle and ground speed are fixed and depend on wind conditions. The logic for glide slope control of such a vehicle is not in TOLA. At best, TOLA can be used to confirm unpowered vehicle glide slope performance for specific known steady state conditions. As such, use of the TOLA glide slope phase is predominantly limited to conventional, powered vehicles.

To do a glide slope calculation requires specific SDF-2 data input and specific autopilot data input. The only landing gear data needed is the R_{gR} input.

a. Glide Slope SDF-2 Data Input

All basic SDF-2 data input (see Section II para 1) is needed. The aircraft must be started close to the desired glide slope position and velocity and be trimmed approximately for the desired conditions. This requires inputs of the proper magnitude for the following SDF-2 variables: HGC7F, THTBD, GAM7D, VG77F, ATAB51, and RGR. If winds are involved, the inputs must include the WTAB tables.

b. Glide Slope Autopilot Data Input

All engine data (see Section II para 3a) must be input. The throttle settings, N, should be close to that required for trimmed power. No drag chute data (see Section II para 3h) is needed. Only ITO, HF, and NF are required in the phase begin data (see Section II para 3c). ITO must have a zero value and NF should have a one value to end the calculation at the HF altitude. The other phase begin input data is not needed unless one desires the calculation to go into the flare phase, hold mode, etc. No takeoff data is needed (see Section II para 3d).

All glide slope maneuver data is needed (see Section II para 3e). The data input here requiring careful scrutiny is ALPHDL, DELEPS, DELSIG, RFH, PGS, RFY, and PHIC. ALPHDL should not exceed the stall conditions for the aircraft. DELEPS and DELSIG determine the accuracy of the glide slope position control and should be approximately 0.1 degree. To see the long period motion after a perturbation (i.e., wind changes, engine failures, etc.), PGS and PHIC must be zero. If it is desired to control the long period oscillations, RFH, PGS, RFY, and PHIC must be appropriately selected in sign and magnitude, which can be selected easily with a knowledge of basic aircraft performance and the aircraft input data. The flare, hold, and landing roll maneuver data (see Section II para 3f, 3g, 3h) is not needed. Engine failure in the glide slope is staged through the variables H1 and H2 (see Section II para 3i) and their associated arrays IH1 and IH2. No brake condition data (see Section II para 3j) is needed for the glide slope. The four autopilots pitch, yaw, roll, and throttle must be built by judicious selections of the constants associated with each.

(1) Pitch Autopilot. The data input here (see Section II para 3k) is, for the most part, self explanatory. That data input requiring careful examination is ALPDL, DELALA, RFALPH, and PSH. ALPDL is used to detect a discontinuous change in α_d (for example, on wind changes and transition from glide slope to flare logic) thru the $\dot{\alpha}_d$ term, and prevent the large $\dot{\alpha}_d$ rate from entering the autopilot (see Appendix I). The ALPDL value must be larger than the $\dot{\alpha}_d$ expected in the flare.

Since the discontinuities α_d produce very large rates, it is safe to pick a sizeable value for ALPDL (i.e., like 2 or 3 deg/sec) and be assured that legitimate $\dot{\alpha}_d$ signals are not limited. DELALA determines the accuracy of the angle of attack control. A DELALA value of 0.01-0.02 degree is sufficient for good control. The constants RFALPH and PSH determine the pitch control of the aircraft. It is left up to the user to choose appropriate values for the particular aircraft system being simulated. Suffice it to say, that values can be easily obtained (with a basic knowledge of aircraft pitch performance and the aircraft input data) that control the aircraft to the α_d command.

(2) Yaw Autopilot. The data input here (see Section II para 3ℓ) is self explanatory. As with the pitch autopilot, the appropriate values of the constants RFB, PSR, RFPSI, and PSPSI, depend on the aircraft system and are to be determined by the user.

(3) Roll Autopilot. Comments on the data input here (see Section II para 3m) is much the same as with the yaw autopilot.

(4) Throttle Autopilot. The data input here (see Section II para 3n) is self explanatory.

No brake autopilot data input (see Section II para 3o) is needed for the glide slope. The control response data input (Section II para 3p) is neeed for the glide slope; the data is self explanatory. The initialization input data (see Section II para 3q) and the autopilot output indicators (Section II para 3r) are self explanatory. No specific staging (see Section II para 4) is needed in the glide slope except the cards at the end of the data deck (see Section II para 4g).

2. FLARE

The flare guidance laws develop a constant acceleration maneuver appropriately limited by touchdown conditions. To achieve the requested acceleration vector in general requires two control degrees of freedom (i.e., angle of attack and power). Upper and lower bounds exist on both

angle of attack and power, so a situation can exist where the requested acceleration vector is outside the control capability of the aircraft. In such a case, the control variable magnitudes used are those that give the least vector error in the requested acceleration vector. The additional input (i.e., other than that required for glide slope) for the flare is as follows:

All gear input data (see Section II para 2) is needed. In the phase begin input (see Section II para 3c) NF must be given a zero value. As previously discussed (Section II para 3c), DELTAH should always have a nonzero, positive value (i.e., like 1. ft). However, if a decrab or tail down constraint maneuver is expected, DELTAH should be large enough (note DELTAH is approximately the distance between the bottom tire surface of the main gears and the runway) to give the autopilot sufficient time to perform the required maneuver. NLRI should have the value one to stop the calculation on impact.

All flare maneuver input data (see Section II para 3f) is needed. That data requiring careful input is DA, TL, and TU. For an accurate flare α_d search, DA should be 0.01-0.02 degree, etc. DA should at least be as small as DELALA in the pitch autopilot. TL and TU determine the thrust range allowed during the flare maneuver. If the vehicle is not powered, TL and TU must be given zero values. In the hold maneuver data (see Section II para 3g), the kill engine indicator array, KE, and the tail down constraint PM are needed. Engine failure (see Section II para 3i) in the flare is staged on the runway altitudes HR1, HR2, and their associated arrays IHR1 and IHR2. In the pitch autopilot input (see Section II para 3k), PSH2, RFALP2, and DELQC2 must be added. Note that in the yaw autopilot data input, the overcontrol constants PSR and PSPSI must have opposite signs. Two stages are required to get the flare to terminate on runway impact: stage gears into program; smooth impact stage (see Section II paras 4a and 4b).

To start the problem in the flare requires the data input of HGC7F to be (Section II para 1) less than the flare altitude HF (see Section II para 3c). To start the problem in the hold mode requires the appropriate input of XRF and HRF (Section II para 3c and Reference 1, pg 182) and the input of ALPDES and TTD (Section II para 3g).

3. LANDING ROLL

The vehicle impact section of the landing roll problem is general in that it can simulate the ground impact of a rigid main structure with up to five independent oleo struts. The control logic for the landing roll, however, is specialized to aerodynamic lifting vehicles which land horizontally. Impact of unconventional aircraft and vehicles which do not land horizontally can be determined, however, under the restriction that all control variables remain fixed.

a. Horizontal Landing

If a drag chute is employed, the chute data (Section II para 3b) must be input. If the problem starts after impact, KP must have a one value (Section II para 3c) and the time of impact, TI, must be given an initial value. The indicator NLRI must have a zero value. The runway stopping conditions VS, XS, and TS must also be input.

All landing roll maneuver data (Section II para 3h) must be input. Engine failure in the landing roll is sequenced through the variables TR1 and TR2 (Section II para 3i) and their associated indicator arrays ITR1 and ITR2. The brake condition input data (Section II para 3j) is needed. In the pitch autopilot data (Section II para 3k), TST, DELQF, and DELFD1 must be input. The brake autopilot data (Section II para 3o) is needed. Note that the MBL array should always contain zeros and that DELTAW must be small enough to give accurate control around PD (the relationship between DELTAW and PD depends on the shape of the coefficient of friction - percent skid table, FTAB03 around the value PD). The first three stages (Section II paras 4a, 4b, and 4c) are a must. The spoiler aero stage is needed if spoilers are used in the landing roll. The rest of the stages can be included at the users descretion.

b. Fixed Control Variables

The usefulness of this option for unconventional vehicles (such as STOL and VSTOL) depends upon the reality of the fixed control variable assumption. A constant body oriented thrust vector can be obtained by input of DLFXP, DLFYP, and DLFZP in the SDF2 data (see pg 17) along with an INDTFF value at zero (see pg 52; this will zero the thrust received from the thrust routine). Fixed pitch, yaw, and roll trim can be obtained by eliminating all input of aerodynamic coefficients associated with elevator, rudder, and aileron deflections (note this automatically zeros these coefficient) and by appropriate input of ATAB10, ATAB24, ATAB38, ATAB51, ATAB65, and ATAB80 (see pgs 26-30). The aerodynamics can be completely deleted by an INDAER indicator value of zero (see pg 51).

4. TAKEOFF ROLL

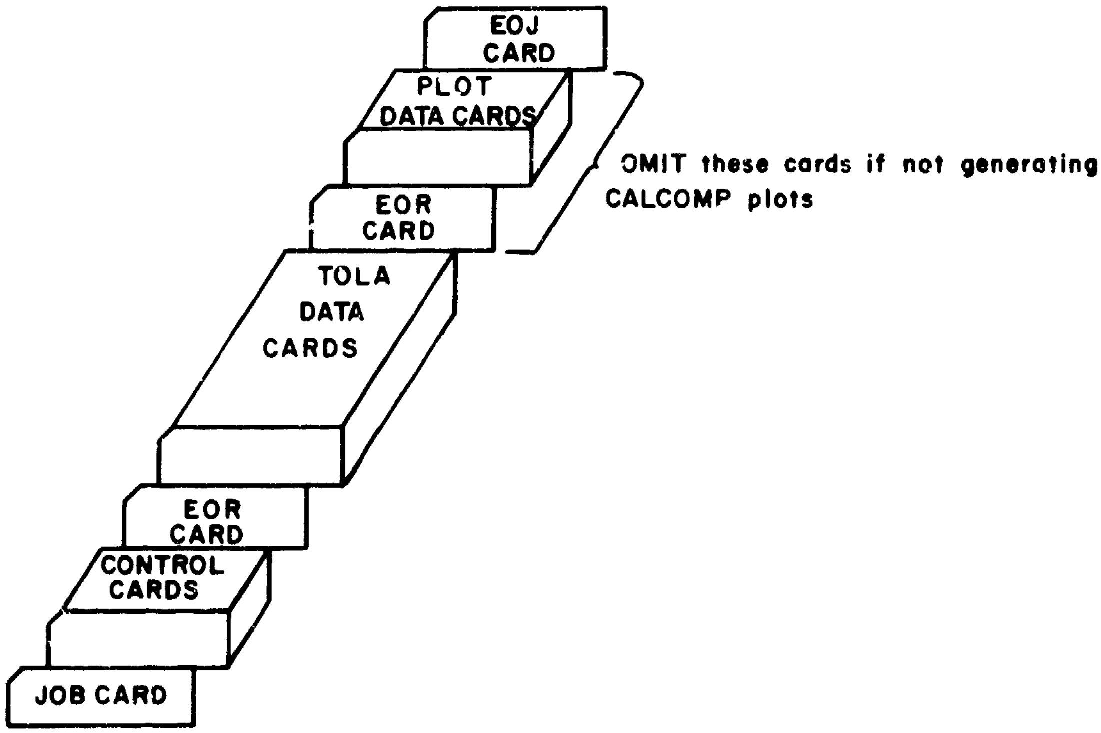
The takeoff roll should start from a near equilibrium condition for the aircraft strut system with the engines at the takeoff throttle setting. The takeoff termination altitude, HS (Section II para 3c - this is normally the altitude to clear a 50-ft obstacle) is needed. The takeoff condition data (Section II para 3d) is needed. Engine failure during takeoff can be staged on the variables XRF1 and XRF2 (Section II para 3i) through their associated arrays IT1 and IT2. DELQTO must be added to the pitch autopilot (Section II para 3k). The first three stages (Section II paras 4a, 4b and 4c) are a must.

SECTION VIII

DECK SETUP

1. DECK STRUCTURE

Running the TOLA computer program requires a particular deck setup. The deck structure is presented as a guide only in determining this setup.



An end of record (EOR) card is a 7, 8, 9 punched in column 1 and an end of job (EOJ) card is a 6, 7, 8, 9 punched in column 1.

2. CONTROL CARDS

A. Execute TOLA where TOLA is a binary file on permanent file TOLACP, Cyle 1.

```
(Job card)
ATTACH,TOLA,TOLACP,ID=XXXXXXX,CY=1.
TOLA.
(end of record)
[Data cards]
(end of job)
```

B. Execute TOLA where TOLA is a binary file on permanent file TOLACP, Cycle 1; generate a data tape; and generate a CALCOMP plot tape from the data tape. The plot program is a binary file on permanent file TOLAPLT, Cycle 1.

```
(Job card)
ATTACH,TOLA,TOLACP,ID=XXXXXXX,CY=1.
LABEL,TAPE13,W,L,=PLTDATA,VSN=LXXXXX.  RING IN
TOLA.
REWIND,TAPE13.
REQUEST,TAPE7,HI, N,VSN=LXXXXX.  RING IN
ATTACH,PLTOLA,TOLAPLT,ID=XXXXXXX,CY=1.
PLTOLA.
(end of record)
```

[Data cards for TOLA]

(end of record)

[Data cards for PLTOLA]

(end of job)

C. If the TOLA computer program is on MT, replace the "ATTACH,TOLA, TOLACP,ID=XXXXXXX,CY=1." card with the following card in examples a and b above:

REQUEST,TOLA,MT,E,VSN=LXXXXX. RING OUT

3. CALCOMP PLOTTING INPUT

The following data is required in order to generate CALCOMP plots by the PLOT Tape Generating Program (PLTOLA).

A. Data generated on file TAPE13 (disk or tape) by TOLA. The input required by TOLA to generate data on file TAPE13 is described in V.3.s., page 64.

B. The following may be read from cards on the input file using the NAMELIST feature of Fortran Extended with the group name of INPUT. If the value of any variable is the same as its nominal value, it is not necessary to read it as input.

VARIABLE NAME	NOMINAL VALUES	VALUES	DESCRIPTION
NCASES	1		Number of sets of data or cases to be plotted
ISDFR	1	1	Rigid body data is stored on tape
		0	Rigid body data is not stored on tape
ISDF	0	0	Do not plot rigid body data
		1	Plot rigid body data
ISTPR(i)	1	1	Landing gear data for gear i is stored on tape
		0	Landing gear data for gear i is not stored on tape
ISTPL(i)	0	0	Do not plot landing gear data for landing gear i.
		1	Do plot landing gear data for landing gear i.
IL	0	0	Do plot lower chamber pressure and 2nd piston plots.
		1	Do not plot lower chamber pressure and 2nd piston plots.
TFIRST	0.		Trajectory time to begin plotting
TLAST	0.		Trajectory time to stop plotting If both TFIRST=TLAST=0., the entire time history on tape will be plotted.
PLTINT	1	K	Plot every Kth point
FCTR	1.0		The current factor all coordinates are multiplied by. That is, the plot is made larger or smaller if FCTR is greater than 1. or less than 1. For example, if it is desired that the plots to be 25% of the original size, let FCTR=.25
XL	7.2		Length of X-axis of plot in inches
YL	5.0		Length of Y-axis of plot in inches

c. Some examples of data input are as follows:

(1) Example No. 1. Plot rigid body variables and landing gear variables for gears 1, 3, and 5. Plot every point, and plot entire time history. Assume rigid body and landing gear variables for gears 1,3, and 5 are stored on TAPE13. The input will be as follows:

```
$INPUT ISDF=1,ISTPR=1,0,1,0,1,ISTPL=1,0,1,0,1$
```

(2) Example No. 2. Plot landing gear variables for gear No. 3. Plot every other point from time = 4. to time = 10. seconds. Assume rigid body and landing gear variables for gears 1,2,3,4, and 5 are stored on TAPE13 for time = 0 to 20. seconds. The input will be as follows:

```
$INPUT ISTPL(3)=1, TFIRST=4., TLAST=10., PLTINT=2$
```

(3) Example No. 3. Plot rigid body variables and landing gear variables for gear No. 5. Plot every point and plot entire time history. Assume rigid body and landing gear variables for gears 1,3, and 5 are stored on tape 13. Desire that the size of graphs to be 50% of the original size where the original size of the X-axis is 8 inches and the Y-axis is 6 inches. The input will be as follows:

```
$INPUT ISDF=1,ISTPR=1,0,1,0,1,ISTPL(5)=1,XL=8.,YL=6.,FCTR=.5$
```

REFERENCE

1. AFFDL-TR-71-155, Urban H. D. Lynch, Captain, USAF, and Dueweke, John J., "Takeoff and Landing Analysis Computer Program; Part II - Problem Formulation," June, 1971, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio.